SHOUT
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CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK

No. 9

1910

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WASHINGTON, U. S. A.
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ROBERT S. WOODWARD

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ELIHU ROOT, *Vice-Chairman*
CLEVELAND H. DODGE, *Secretary*

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Finance Committee

SETH LOW, *Chairman*
HENRY S. PRITCHETT
HENRY L. HIGGINSON

* Ex-officio member.

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ARTICLES OF INCORPORATION.

The Carnegie Institution was originally organized under the law governing the organization of corporations in the District of Columbia. Owing to certain limitations in the law, the Trustees deemed it desirable to obtain articles of incorporation from the Congress. Accordingly, articles of incorporation were prepared, submitted to the Congress, amended by the Congress, and enacted into statute by the Congress and the signature of the President.

Organization under the new articles of incorporation was effected on May 18, 1904. Resolutions were passed electing the same Executive Committee and officers as those of the Carnegie Institution organized in 1902 and continuing all instructions and authorizations given to the Executive Committee by the old organization.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time

to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause

existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz, an Executive Committee and a Finance Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees and of the Executive Committee. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting.

8. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property shall be deposited in such safe deposit or other corporation and under such safeguards as the Trustees and Executive Committee shall designate; and the moneys of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

Eighth Meeting of the Board of Trustees

December 13, 1910.

ABSTRACT OF THE MINUTES OF THE EIGHTH MEETING OF THE BOARD OF TRUSTEES.

The meeting was held in Washington, in the Board Room of the Administration Building, on Tuesday, December 13, 1910, and was called to order at 10 o'clock a. m. by the Chairman, Mr. Billings.

Upon roll-call by the Secretary, the following members of the Board were found to be present: John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Henry L. Higginson, Charles L. Hutchinson, S. Weir Mitchell, Andrew J. Montague, William W. Morrow, Wm. Barclay Parsons, Henry S. Pritchett, Elihu Root, Martin A. Ryerson, Charles D. Walcott, William H. Welch, Andrew D. White, George W. Wickersham, Robert S. Woodward.

The minutes of the seventh meeting were approved as printed in abstract and submitted to members of the Board of Trustees.

The reports of the President, the Executive Committee, the auditor, directors of departments, and grantees of the Institution, and a special report of the Finance Committee were presented and considered.

The following general appropriations for 1911 were authorized:

Publication	$50,000
Administration	45,000
Division of Publications	9,000
Departments and Laboratories	443,797
Minor grants and research associates	47,700
Index Medicus	12,500
Classics of International Law	10,000
Insurance fund	15,000
	632,997

After lengthy discussion amendments were made to certain By-laws affecting the mode of election of Trustees, the date of the annual meeting, the custody of the seal and of the securities of the Corporation, and the appointment of the auditor.

Vacancies in the Board of Trustees were reported, due to the death of Mr. Hitchcock, the death of Mr. Lindsay, and the non-acceptance of election of Mr. Eliot. Balloting to fill the vacancies resulted in the election of the following persons to membership in the Board:

Dr. Simon Flexner, of New York.

Mr. Robert Somers Brookings, of Missouri.

Dr. Henry Pickering Walcott, of Massachusetts.

The Board adjourned at 1 o'clock and 5 minutes p. m.

Memorial

Darius Ogden Mills

1825-1910

Darius Ogden Mills was elected a member of the original Board of Trustees of the Institution on January 4, 1902. He died on January 3, 1910, shortly after his resignation as a member of the Board had taken effect. During his entire connection with the Institution he served as one of the three members of the Finance Committee and gave to the Institution the benefit of his exceptionally sound judgment in financial matters.

Mr. Mills's varied interests led to activities in educational circles which were unusually fruitful and of much benefit to society. He served as regent and treasurer of the University of California from 1868 to 1880 and founded there a professorship of moral and intellectual philosophy. He also served as one of the first trustees of the Lick estate and the Lick observatory. After coming to New York in 1880 he built the Mills hotels and established training schools for nurses. He accepted election as president of the New York Botanical Garden and also became a trustee of the American Museum of Natural History, of the Metropolitan Museum of Art, and of the American Geographical Society.

Ill health attended his later years and prevented active participation in the affairs of the Carnegie Institution of Washington. He was, however, ever mindful of its interests and recognized the importance of its work, and his absence will be felt in the loss of a keen judgment of men and affairs, and of an intelligent and sympathetic comprehension of the mission of the Institution.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1910.

REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

In compliance with Article IV of the By-laws of the Carnegie Institution of Washington, I have the honor to submit the following report on the present status of the interests of the Institution and on the events and the work thereof for the fiscal year ending October 31, 1910, along with recommendations of appropriations for the ensuing year and with sundry suggestions and recommendations concerning other questions which have been under consideration during the past year.

Explanatory Statement.

This report is the ninth annual report of the Institution and is presented under the following principal heds:

1. Work of administration.
2. Résumé of investigations of the year.
3. Publications.

WORK OF ADMINISTRATION.

The more noteworthy events in the history of the Institution during the past year are the dedication in December, 1909, of the Administration Building; the inauguration at that time of an annual series of semi-popular lectures explanatory of the researches of the Institution; the inauguration on the same occasion of a series of periodical exhibits of the work accomplisht by the departments of investigation and the divisions of publication and administration; the successful completion of the first voyage (of 8,000 miles) of the non-magnetic ship *Carnegie*, and the beginning of a second cruise, which is expected to require three years, by this novel craft; and the fourth conference of the International Solar Union held at the Solar Observatory of the Institution on Mount Wilson, California, from August 29 to September 4, 1910.

Salient Events of the Year.

The administrativ staff of the Institution movd into the Administration Building on November 8, 1909; and altho the building was not then completed and equipt in all its parts, it was so far advanced in the two upper stories as to permit immediate use and a formal dedication on the evening of Monday, December 11, 1909. On this occasion the Trustees and their guests assembled in the lecture room of the building and brief addresses were made by the Chairman and Vice-Chairman of the Board of Trustees and by the Founder of the Institution. Following these ceremonies a lecture on the work of the Solar Observatory was given by Prof. George E. Hale, Director of that establishment. The Trustees and their guests were then invited to inspect the exhibits instald in the rooms of the uppermost floor of the Administration Building by the ten principal departments of research of the Institution and by the divisions of publication and administration.

During the afternoons of a week beginning December 13, 1909, the Administration Building was opend to the public, and between 3,000 and 4,000 visitors inspected the building and the exhibits instald therein. This was the first opportunity the Institution has had of indicating in a concrete way the plan, scope, and results of its work, and the comprehension and appreciation of this work by the public have been very gratifying. As an aid to the dissemination of semi-popular information concerning the Institution and its activities an illustrated pamflet of 32 octavo pages was printed for this occasion and distributed to guests present at the dedication and to visitors who came later to inspect the building and the departmental exhibits. Probably nothing hitherto done by the Institution has helpt so much to give correct popular information and to remov false popular impressions concerning the objects of the Institution as the publication of this pamflet.

The opportunities thus afforded for a summary view of the development, the progress, and the history of the Institution during the first eight years of its existence provd alike advantageous to the Trustees, to the investigators, and to the public. The directors of the principal departments of research were enabld for the first time to become acquainted with one another and to confer as a body with the President concerning matters of common interest in departmental researches and in departmental administration. The conferences held on this occasion with these directors were so fruitful that it appears desirable to hold them annually during the week of the annual meeting of the Board of Trustees.

In proportion as the work of the Institution is novel, advanced, or fundamental it will be difficult to understand and slow to receiv popular appreciation. Some of it, indeed, must be expected to meet initially with disapproval because misunderstood. Hence, to counteract false impressions, to keep the investigator in touch with his contemporaries in other occupations, and to maintain an intelligent public interest in the work of the Institution, it seems essential to hold exhibitions, at intervals of three to five years, similar to that which provd so instructiv a year ago.

A detaild account of the remarkable success of the non-magnetic ship *Carnegie* will be found in the annual report of the Director of the Department of Terrestrial Magnetism. It may suffice here to state that her first cruise in the Atlantic Ocean (of about 8,000 miles) not only demonstrated her fulfilment of all expectations as a floating magnetic observatory, but also brought to light important errors in the magnetic elements shown on the best sailing charts of the Atlantic. The perfection of observation on this ship is fitly supplemented by a promptness of computation which enables her scientific staff to furnish the results redy for publication as fast as the observations are made. Thus the results of her first cruise were soon in print and are alredy in use by mariners. After returning to Brooklyn in February, 1910, she had her copper sheathing attacht, and was thoroly overhauld and refitted for a three years' cruise, on which she set sail June 29, 1910. At

the present time she is off the coast of South America between the ports of Para and Rio de Janeiro, having had a successful voyage of about 9,000 miles when last heard from.

An event of unusual importance in astrophysical science and of special interest to the staff of the Solar Observatory was the meeting of the International Solar Union held at Pasadena and on Mount Wilson, August 29 to September 4 last. Attracted by the novel methods and equipment of the Solar Observatory and by the remarkable results it has alredy achievd, nearly one hundred delegates, about a third of whom were from European countries, held what promises to be one of the most fruitful of international conferences in the history of astrophysics. The counsel, the criticism, and the constructiv suggestions derivd, especially from our distinguisht European colleags, are highly esteemd, not only by the staff of the Solar Observatory but by all members of the Institution interested in physical science. Many of the foren delegates visited Washington on their homeward journeys, and all of these were interested also in the novel enterprises of the Geophysical Laboratory and of the Department of Terrestrial Magnetism.

Summary of Work of Institution to Date.

In the two preceding reports attempts have been made, for the benefit of the reader who has little time for details, to condense into a single paragraf the salient facts indicating the growth and extent of the work of the Institution. Since the period of rapid expansion has now past and since economic conditions must require some degree of contraction of the Institution's activities in the near future, it seems desirable to bring that summary down to date. Additional studies made during the past year of the ramifications of the work of the Institution show that the range of this work and the numbers of investigators and collaborators engaged in its prosecution have been hitherto somewhat underestimated. It now appears that since its organization in 1902 upwards of twelve hundred individuals have contributed in one way or another to the promotion of the researches and the publications undertaken by the Institution. During each of the past five years about five hundred individuals have thus collaborated. Ten independent departments of research and the divisions of publication and administration, each with its staff and assistants, have been organizd and establisht within the Institution itself. In addition to these larger departments of work, numerous special researches, in aid of which upwards of seven hundred grants have been made, have been carried on by research associates and other individual investigators. For the departments of research, two astronomical observatories, five laboratories, and a non-magnetic ship have been built and equipt; while the divisions of administration and publication have been provided with adequate quarters in the Administration Building, at Washington, D. C., completed a year ago.

A full inventory of the property of the Institution to date includes fifty-nine buildings, thirteen parcels of land (held either by clear title or by favor-

able long-term leases), and ten vessels. Investigations have been carried on in more than thirty different fields of research and the geografical range of this work has extended to more than forty different countries. One hundred and sixty-seven volumes of publications, with an aggregate of more than 40,000 pages of printed matter, have been issued directly by the Institution to date, and twenty-five volumes are now in press. These works are distributed gratuitously to a limited list of the greater libraries of the world and they are also offerd for sale at the nominal cost of publication. In addition to these publications issued by the Institution itself, upwards of twelve hundred shorter papers have been contributed to the current journals of the world by departmental investigators, by research associates, and by collaborators.

Except for a few gifts from friends of the Institution and its investigators, the costs of the work accomplisht and of the property acquird have been paid wholly from the interest on the endowment of the Institution. The total amount of funds derivd from this source, from interest on temporary investments and bank balances, and from miscellaneous sources is $4,723,570.45. The total amount of funds appropriated for expenditure to date is $4,947,401, which includes $329,442, which have been reverted and afterwards reappropriated. The total amount expended to date is $4,590,820.90. Of this amount $1,540,840.37 are represented in land, buildings, vessels, equipments, and publications in stock; $371,415.35 have defrayd the expenses of administration; $281,223.96 have been spent for publications, and $2,418,708.45 have been applied directly to the prosecution of research.

General Financial Status of the Institution.

The printed financial statements issued monthly from the offis of administration exhibit the details of receipts and expenditures for each month of any year, the aggregates of receipts and expenditures from the beginning of any year, and the corresponding aggregates for the period which has elapst since the foundation of the Institution. But while these publications show that the present financial status of the Institution is sound and that it may be kept so by living within an income of about $615,000 per year, they make no reference to the very adverse economic condition to which institutions dependent on fixt incomes are now subject. This adverse condition arises from the world-wide increase in prices of commodities and in the cost of living which has been going on since 1897. Conservativly stated, it may be said that the increase in question has been upwards of 20 per cent since the foundation of the Institution; so that the purchasing capacity of our present income of $600,000 per year is no greater than that of the original income of $500,000 would be under such economic conditions as obtaind in 1902. Moreover, existing circumstances point clearly to a still further rise in world prices, or to a still further diminution of the purchasing capacity of the Institution's income. Attention was cald in my report of a year ago to

the limitations imposed on the growth of the Institution by this economic condition, and steps essential to keep expenditures within income were taken in the preparation of the last annual budget. It was necessary, in fact, beginning with the year 1910, to restrict the work of the Institution mainly to existing fruitful enterprises and to prepare for a probable curtailment of them in the near future. These considerations arising from causes external to the Institution should be borne in mind in any attempt to interpret its present and prospectiv financial status.

Financial Statement for Fiscal Year 1909–1910.

The sources of funds available for expenditure during the past year, the allotments for the year, and the balances unallotted at the end of the year are shown in detail in the following statement:

	Unallotted Oct. 31, 1909.	Appropriation, Dec. 14, 1909.	Revertments Oct. 31, 1909, to Oct. 31, 1910.	Total.	Aggregates of allotments and amounts transferd.	Balance unallotted Oct. 31, 1910.
Large grants.....	.....	$417,661	$33,948.28	$451,609.28	$451,609.28	.....
Minor grants.....	$1,000.00	65,800	2,298.28	69,098.28	69,098.28	.....
Research associates and assistants	.....	23,800	.....	23,800.00	23,800.00	.....
Publications	27,194.53	65,000	6,801.89	98,996.42	91,376.26	$7,620.16
Administration...	13,417.76	45,000	147.65	58,565.41	44,011.61	14,553.80
Total.....	41,612.29	617,261	43,196.10	702,069.39	679,895.43	22,173.96

The following list shows the departments of investigation to which the larger grants were made by the Trustees and the amounts allotted from those grants by the Executiv Committee during the year:

Department of Botanical Research	$34,728.00
Department of Experimental Evolution	40,970.00
Department of Economics and Sociology	10,000.00
Geophysical Laboratory	51,020.00
Department of Historical Research	22,700.00
Department of Marine Biology	27,070.00
Department of Meridian Astrometry	35,655.00
Nutrition Laboratory	26,378.00
Division of Publications	9,000.00
Solar Observatory	115,720.00
Department of Terrestrial Magnetism	76,920.00
	450,161.00
Transferd to minor grants	1,448.28
	451,609.28

The fields of investigation to which minor grants were assignd, the names of the grantees, and amounts of the grants are shown in the following list:

Details of minor grants.

Field of investigation.	Names of grantees.	Amount of grants.
Archeology	American School of Classical Studies at Athens	$4,600.00
	American School of Classical Studies in Rome	2,000.00
	Van Deman, Esther B.	1,200.00
	Müller, W. Max	2,000.00
Astronomy	International Solar Union	7,500.00
	Gale, Henry G.	588.79
Bibliografy	Index Medicus	12,500.00
Botany	Huntington, Ellsworth	750.00
	Account of the work of Luther Burbank	2,000.00
Chemistry	Bancroft, W. D.	1,500.00
	Acree, S. F.	1,000.00
	Osborne, T. B.	7,250.00
Geophysics	Jaeger, F. M.	1,600.00
Literature	Sommer, H. Oskar	3,000.00
Mathematics	Morley, Frank	1,200.00
Meteorology	Bjerknes, V.	1,200.00
Paleontology	Wieland, G. R.	1,000.00
	Case, E. C.	1,600.00
Physics	Howe, Henry M.	300.00
Zoology	Castle, W. E.	1,000.00
	Naples Zoological Station	1,000.00
		54,788.79
Transferd	Large grants	12,500.00
	Unappropriated fund	1,809.49
		69,098.28

The following table shows the fields of investigation of research associates and the amounts of their grants:

Field of investigation.	Names of research associates.	Amount of grants.
Astronomy	Kapteyn, J. C.	$2,000.00
	Gale, Henry G.	1,000.00
Chemistry	Richards, Theo. W.	2,500.00
	Morse, H. N.	1,800.00
	Baxter, G. P.	1,000.00
	Jones, Harry C.	1,200.00
	Noyes, A. A.	3,000.00
Geology	Moulton, F. R.	2,000.00
Paleontology	Wieland, G. R.	1,000.00
Philology and linguistics	Hempl, George	1,000.00
Physics	Barus, Carl	500.00
	Nichols, E. L.	3,000.00
Physiology	Reichert, E. T.	1,500.00
Political science	Rowe, L. S.	1,500.00
Terrestrial magnetism	Beattie, J. C.	416.67
		23,416.67
Transferd to unappropriated fund		383.33
		23,800.00

The following grants for publication were authorizd during the year:

Adams, Walter S.	$1,850.00
Allison, Wm. H.	850.00
Baxter, G. P.	800.00
Benedict, F. G., and T. M. Carpenter	1,800.00
Benedict, F. G., and E. P. Joslin	1,200.00
Boss, Lewis	241.59
Campbell, D. H.	2,250.00
Cannon, W. A.	1,400.00
Carnegie Institution of Washington	392.82
Do.	1,200.00
Churchill, Wm.	1,800.00
Davenport, C. B.	676.96
Fish, Carl R.	1,400.00
Goss, W. F. M.	1,350.00
Jones and Strong	3,500.00
Lehmer, D. N.	3,274.55
Lloyd, F. E.	2,500.00
Lutz, F. E.	300.00
MacDougal and Cannon	600.00
MacDougal and Spalding	$600.00
Mayer, A. G.	964.35
Mark and Long	850.00
Müller, W. Max	216.13
Papers from the Tortugas Laboratory	3,200.00
Perrine, Charles D.	192.29
Republication of Classics of International Law	15,000.00
Richards, T. W.	450.00
Smith, E. F.	4,500.00
Sommer, H. O.	7,500.00
Van Deman, E. B.	517.57
	61,376.26
Transferd:	
Large grants $10,000	
Unappropriated fund 20,000	
	30,000.00
	91,376.26

The sources and amounts of the revertments from November 1, 1909, to October 31, 1910, inclusiv, are shown in the following.

Large Grants:		
Transferd from Publication	$10,000.00	
Insurance	10,000.00	
Minor grants	12,500.00	
Department of Experimental Evolution, purchase of additional land	1,448.28	
		$33,948.28
Minor Grants:		
Transferd from Large grants	1,448.28	
International Solar Union, Grant No. 620	850.00	
		2,298.28
Publication:		
Putnam, Herbert, Grant No. 290	129.69	
Spalding, V. M., Grant No. 532	657.62	
Reichert and Brown, Grant No. 581	1,239.93	
Ward, W. H., Grant No. 514	2,472.19	
Benedict and Carpenter, Grant No. 594	200.87	
Richards, T. W., Grant No. 636	51.81	
Barus, Carl, Grant No. 593	140.44	
California State Earthquake Investigation Commission, Grant No. 467	653.29	
Johnson, R. H., Grant No. 595	117.40	
Benedict and Carpenter, Grant No. 637	827.01	
Robertson, J. A., Grant No. 596	275.37	
MacDougal and Cannon, Grant No. 643	36.27	
		6,801.89
Administration:		
Shipping expenses (Mt. Wilson reprints)	53.47	
Sale of boxes	26.80	
Sale of waste paper	10.92	
Operating equipment (Bausch and Lomb)	18.00	
Building grounds (refund on sidewalk)	38.46	
		147.65
		43,196.10

Summary of Receipts and Expenditures of the Institution to Date.

The aggregate receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refund on grants, and miscellaneous items to date is $4,923,820.45, as shown by the following table:

Year ending Oct. 31—	Interest.		Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
	Endowment.	Bonds and bank deposits.				
1902.....	$250,000.00	$9.70	.....	.....	$1,825.52	$251,835.22
1903.....	500,000.00	5,867.10	$2,286.16	.....	101.57	508,254.83
1904.....	500,000.00	33,004.26	2,436.07	$999.03	.....	536,439.36
1905.....	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906.....	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907.....	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908.....	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909.....	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910.....	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.77
	4,500,000.00	157,710.17	47,666.79	10,000.23	*208,443.26	4,923,820.45

*Of this amount, $200,250 were received from the sale of bonds in 1908, 1909, and 1910.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heds, namely: (1) investments in bonds and on account of Administration Building; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The actual expenditures under these heds for each year since the foundation of the Institution are shown in the following table:

Year ending Oct. 31—	Investments in bonds and on account of Administration Building.	Large projects.	Minor projects, special projects, research associates and assistants.	Publications.	Administration.	Total.
1902.....	.....	.....	$4,500.00	.....	$27,513.00	$32,013.00
1903.....	$100,475.00	.....	137,564.17	$938.53	43,627.66	282,605.36
1904.....	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905.....	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906.....	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907.....	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908.....	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909.....	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910.....	57,889.15	437,941.40	73,464.63	49,067.00	44,011.61	662,373.79
Total..	656,442.52	2,583,677.55	898,204.28	281,223.96	371,522.59	4,791,070.90

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended:

Administration:		
Building, site, and equipment		$312,307.93
Publications:		
Stock on hand and outstanding accounts (October 31, 1910)		165,359.06
Department of Botanical Research (September 30, 1910):		
Buildings, offis, and library	$23,477.29	
Apparatus	6,713.75	
Operating appliances	8,555.28	
		38,746.32
Department of Experimental Evolution (September 30, 1910):		
Buildings, offis, and library	38,131.12	
Laboratory apparatus	4,095.37	
Operating appliances and grounds	15,860.03	
		58,086.52
Geophysical Laboratory (September 30, 1910):		
Building, library, operating appliances	110,712.61	
Laboratory apparatus	58,585.75	
Shop equipment	10,567.90	
		179,866.26
Department of Marine Biology (September 30, 1910):		
Vessels	12,712.55	
Buildings, docks, furniture, and library	9,903.58	
Apparatus and instruments	1,741.02	
		24,357.15
Department of Meridian Astrometry (June 30, 1910):		
Buildings and operating appliances	13,518.90	
Apparatus and instruments	2,394.34	
		15,913.24
Nutrition Laboratory (September 30, 1910):		
Building and offis	108,492.60	
Laboratory apparatus	10,218.69	
Shop equipment	1,895.83	
		120,607.12
Solar Observatory (August 31, 1910):		
Buildings, grounds, road, and telephone line	113,328.52	
Shop equipment	18,953.25	
Instruments	265,888.95	
Furniture and operativ appliances	40,147.50	
Hooker telescope	37,404.14	
		475,722.36
Department of Terrestrial Magnetism (September 30, 1910):		
Offis	4,250.83	
Instruments	24,410.19	
Vessel and ocean equipment	116,976.57	
Land equipment	4,236.82	
		149,874.41
		1,540,840.37

Cost of Site, Administration Building, and Its Equipment.

A summary statement of the items which go to make up the total cost of the site, construction, and equipment of the Administration Building is given in the following table:

To whom paid.	Object.	Cost.	Total.
T. J. Fisher Co.	Site		$63,015.09
J. E. and A. L. Pennock	Construction of building	$216,132.58	
Carrère and Hastings	Architects' fees and expenses.	11,937.93	
Fidelity and Deposit Co.	Builders' bond	375.00	
Newton and Painter	Plans for heating plant	112.71	
Harry Alexander	Extra electrical wiring	12.85	
M. C. Hazen	Survey of site	10.00	
			228,581.07
Sterling Bronze Co.	Electric and gas fixtures	7,614.22	
General Fire Proofing Co.	Steel Shelving	2,972.24	
R. B. Caverly, Inc.	Toilet fixtures	189.50	
Franklin Electric Mfg. Co.	Electric light bulbs	175.00	
Copeland Co	Awnings	43.50	
			10,994.46
Davenport Co	Offis furniture	2,968.00	
Derby Desk Co	Offis furniture	674.00	
W. and J. Sloane	Rugs	2,332.99	
Bausch and Lomb Optical Co.	Baloptican lantern	657.43	
A. T. Thompson and Co.	Baloptican light feed	134.00	
Allen Shade Holder Co.	Window shades	558.65	
E. T. Burrowes Co.	Window and door screens	214.60	7,539.67
Total			310,130.29

Status of Building Fund.

In connection with the information furnisht by the last table, it is of interest to note that the "building fund" set aside in 1902 has sufficed not only to defray the costs of the site and of the construction of the Administration Building, but also to pay for nearly all of its equipment, including fixtures and furniture, the total cost of which latter, as shown by the table, being $18,534.13. The amount of the "building fund" and the interest thereon up to the end of the year 1909, when the building was completed, are shown as follows:

Amount of investment	$250,000.00
Interest, 1903	1,500.00
1904	8,500.00
1905	10,375.00
1906	10,501.80
1907	10,000.00
1908	10,000.00
1909	9,038.89
Total	309,915.69

It should be stated also in this connection that interest-bearing railway securities of the nominal value of $100,000 are still held from this "building fund," subject to demand call from the current cash account of the Institution. This retention has been made possible by reason of the relativly large sum pledgd but not promtly cald for by the publication account, and by reason of conservativ attention to current expenses and to bank balances.

Utility and Cost of Maintenance of Administration Building.

The experience of the past year has demonstrated the utility, from all points of view, of the dignified and permanent home for the Institution afforded by the Administration Building. It has provd especially satisfactory to the resident administrativ staff by reason of its fitness to mitigate the severity of a tropical summer. It has provd to be admirably adapted also to the storage and to the handling in receipt and shipment of the Institution's publications. These are now, for the first time, reasonably safe from damage either by fire or by the excessiv humidity of the summer season in Washington. As explaind in a later section of this report, these publications now include about 70,000 individual volumes and represent a cost value of about $165,000; and while there is reason to think that the present accumulation of books is greater than it will be in the future, the need of the provision made for safe storage is evident.

As to the cost of maintenance of this building, it may suffice to state the fact that the aggregate expense of the past year has fallen within the estimates for this purpose approvd in the budget of a year ago. It may be stated also that there is no reason to fear any material increase in this cost in the near future, altho the general rise in prices and the natural increase in the business of the Institution as a shipping and intelligence agency will probably cause some increase in this expense.

In respect to this subject, it seems desirable to point out that we have no adequate theory to guide us in determining in any new instance what should be the best ratio of cost of administration to total income. In actual experience it appears to be the universal practis to charge to administration the cost of any necessary work which does not fall obviously into some other category. This was done, for example, in the case of the publication work of the Institution until the establishment of a division for that work a year ago. Similarly, the costs of storage and shipping of publications and the costs entaild by an extensiv but fruitless portion of offis correspondence may be cited as inappropriate charges in the administrativ budget. But while it will be practicable and proper to make the sales of publications pay the expenses connected with them, it is not yet feasible to make the wasteful correspondence referd to pay any part of the expense it requires. These concrete cases are cited, however, only to indicate the complexity of the subject and the difficulty in the way of reducing the ratio in question to a rational minimum. In the meantime it may be observd that while the volume of productiv work of the Institution has greatly increast and the volume of the unproductiv work scarcely diminisht in recent years, the cost of administration, however it may be reckond, has remaind nearly stationary.

Statement of Insurance Fund.

The present status of the insurance fund of the Institution is shown by the following statement:

Appropriation for the year 1909	$15,000
Appropriation for the year 1910	10,000
Accrued interest, 1909	450
Accrued interest, 1910	843
Insurance receivd February, 1910, for fire loss of quarters of Solar Observatory	3,990
Insurance receivd March, 1910, for loss by fire of chemicals and apparatus in laboratory of Dr. T. B. Osborne	727
	31,010
Allotment for rebuilding the quarters of Solar Observatory, made March, 1910	10,000
Amount of fund on hand	21,010

RÉSUMÉ OF INVESTIGATIONS OF THE YEAR.

Work in the ten specially organizd departments of research in the Institution has gone forward during the year with increasing vigor and with increasing productivity. All of these novel establishments may be said to have now past the preliminary stages of organization, equipment, and tentativ experience, so that henceforth their efforts and resources may be still more effectivly directed and applied. Most of the departments have been strengthend during the year by additions to the staffs of investigators and by accessions to equipment and other facilities, some of which latter have come thru the generosity of friends, who have thus shown their appreciation of departmental researches.

Progress in Departments of Research.

But while the existing status of departmental affairs is in general highly satisfactory, it appears essential to again call attention to the fact that with present income and current economic conditions no further expansion of departmental appropriations can be expected. It may be necessary, on the contrary, to curtail research in the departments in order to keep the aggregate expense of the Institution within income. It need not follow, however, that this prospectiv diminution in financial outlay will cause a corresponding diminution of productivity, for work of investigation, like work along other novel lines, is usually most costly in the preliminary stages.

Referring to the current Year Book for interesting and instructiv details in the reports of the directors of departments, some of the salient features of their activities are summarizd in the following paragrafs.

Department of Botanical Research.

It is a maxim in the pursuit of physical science to proceed from the simpler to the more complex in any attempt to discover the relation among observd facts. In accordance with this maxim, the hedquarters of the Department of Botanical Research are located in a desert area where the facts of plant life are exhibited, in general, in their simplest, tho often extreme and highly specialized, relations. But even under these favorable conditions plant life presents

problems whose solution requires aid from many sciences other than those which are commonly held to make up biology, and especially from chemistry, physics, and meteorology. Thus the researches of this department call for much collaboration and for a wide range of observation, experiment, and determinate analysis.

During the year the Director of the department has continued his investigations on the water-balance of succulent plants, on the conditions of vegetable parasitism, on the variability in plant species induced by chemical treatment of their seeds, and on the influences of climate on plant organisms. In collaboration with Prof. Ellsworth Huntington, research associate of the department during a portion of the year, the Director has begun a general climatological study of the region about Tucson, giving special attention to the factors and effects of the Santa Cruz and Asuncion river systems.

Dr. Cannon, of the permanent departmental staff, has given attention especially to his elaborate investigation of the root systems and habits of desert plants. For the purpose of extending the range of his studies in this fundamental subject he visited the Sahara Desert and will spend most of the year in that advantageous field for both comparativ and direct observations. Some of the more important conclusions alredy establisht in respect to this inquiry are set forth in the Director's current report.

Dr. Shreve, also of the permanent staff of the department, while occupied with the more general problem of the relation of plants to climate in the United States, has also carried on special investigations of the vital statistics of plants in the vicinity of the Desert Laboratory; of the vegetation in the Santa Catalina Mountains; and of the physiological characteristics of the lace-fern family of plants. In the first of these researches he has been aided by the collaboration of Dr. Livingston, who resignd from the staff of the department a year ago to accept a professorship in Johns Hopkins University.

Observations on the phenomena presented in the drying up of Salton Sea, and especially on the influx of vegetation over the bared strands and islands of this slowly retreating body of water, have been continued during the year. In this work a series of soil analyses of the strands has been secured thru the cooperation of Mr. E. E. Free, of the Bureau of Soils of the U. S. Department of Agriculture.

Publications by members of the department issued during the year are shown in the list on pp. 32–33 and in the bibliography of the Year Book. Others in press are Nos. 131, 139, 141. One of these, No. 139, on the Guayule, a desert rubber-producing plant of considerable economic importance, is the work of Prof. Francis E. Lloyd, formerly a resident associate of the department, but now a member of the faculty of Alabama Polytechnic Institute.

So many converging lines of fruitful research are now being pursued by this department that it is difficult to summarize fitly its current progress.

Department of Experimental Evolution.

This duty must be accorded, in fact, as in all other cases, to the Director of the department concernd, in his annual reports and in his more detaild publications. From the abstract scientific point of view the most interesting feature of this work is found in the introduction of statistical and other quantitativ methods, whereby biology is now passing from the first to the next higher stage in the development of a science. From the more popular points of view the work in question is of special interest by reason of its bearing on the economics of plant and animal breeding and by reason of the light it is certain to shed on the laws of human heredity.

So large and so intricate a field of work calls for varid objects and subjects of experimentation and for the resources of many collateral sciences. Thus, studies of heredity have developt the necessity of certain investigations in physiological chemistry, and a small equipment for this purpose has been fitted up in a room of the main laboratory building and put in charge of Dr. R. A. Gortner. Similarly, for studies of the changes which organisms undergo in dark caves and in deep waters, an artificial cave has been added to the basement of the laboratory, and the work of experimentation by means of this adjunct has been assignd to Dr. A. M. Banta, whose erly investigations in this line were printed by the Institution some years ago in Publication No. 67.

In order to meet the increasing needs of the department for land for the cultivation of plants and the breeding of animals, the Institution purchast in January, 1910, a tract of 21 acres of very desirable land lying about a mile east of the laboratory. It may be noted also that Goose Island, in Long Island Sound, acquird for the department a year ago, has alredy been put to good use in experiments on plants and animals in a state of isolation.

It is a source of plesure to record that two friends of the department have shown their appreciation of the Director's enterprise by gifts which will greatly aid him in the prosecution of his work: one has supplied a wharf and a shelter house on Goose Island; the other has furnisht funds essential to establish, near to but independently of the laboratory, an offis for the collection and interpretation, under the direction of Dr. Davenport, of data bearing on human heredity.

Erly in the current year the Executiv Committee requested Prof. Henry W. Farnam (who was appointed Chairman of the Department of Economics and Sociology soon after the deth of Dr. Wright) to submit a report on the status of the work of the department, along with recommendations for its future conduct. Accordingly, a comprehensiv report was presented to the Executiv Committee April 18, 1910, and subsequently printed in full and transmitted in this form to all members of the Board of Trustees. It is assumed, therefore, that a review of this report is not needed here. It should be stated, however, that

Department of Economics and Sociology.

the Executiv Committee, after considering this report at length, authorizd by resolution adopted May 16, 1910, a continuation of the work in question along the lines hitherto followd, with the understanding that it be brought to such a state of completion as may prove practicable under the limitations of the balances of appropriations alredy made to the department.

In addition to the special report referd to above, attention should be invited also to the annual report of progress renderd by the Chairman of the department in the current Year Book. From this it is seen that a large number of individuals have collaborated in carrying forward the programs of work adopted for the twelve departmental divisions of research. During the year the conduct of the Division of Labor, originally in charge of Dr. Wright, has been assignd, under favorable conditions, to Prof. John R. Commons, of the University of Wisconsin.

Several volumes of publications arising directly or indirectly from the investigations of the department have been issued during the year thru the agencies of commercial publishers. Two volumes also of the Index of Economic Material in the Documents of the United States, namely, those for Delaware and Kentucky, prepard under the auspices of the department by Miss Adelaide R. Hasse, have been issued as publications of the Institution.

Department of Historical Research.

The removal of the administration offises from the Bond Building a year ago made it practicable for the Department of Historical Research to secure more desirable and somewhat more enlargd quarters than it has hitherto occupied in that building. By reason of this readjustment the conditions for comfort and efficiency of the resident staff of the department have been distinctly improved.

One of the most important works produced by the department has appeard during the year under the title "List of documents in Spanish archives relating to the history of the United States, which have been printed or of which transcripts are preserved in American libraries," Publication No. 124, prepard by Dr. James A. Robertson, now librarian of the Philippine Library, Manila. Two other works of similar import are now in press, namely: "Guide to the materials for American history in Roman and other Italian archives," Publication No. 128, by Prof. C. R. Fish; and "Inventory of the unpublished material for American religious history in Protestant Church archives and other repositories," Publication No. 137, by Prof. William H. Allison, now of Colgate Theological Seminary.

Manuscripts have been receivd also of the "Guide to materials for American history in German archives," by Prof. Marion D. Learned, and of the "Guide to materials for the history of the United States in Mexican archives," by Prof. Herbert E. Boulton. Progress is likewise reported in respect to a guide to materials for American history in the archives of Paris, in preparation by Mr. Leland, of the department staff; and in the rearrangement of a guide to British materials made necessary by a reclassification of the British Public Record Office promulgated after Prof. C. M. Andrews had the preparation of this guide well under way.

Many other researches in progress are described in the Director's current report, to which reference must be made for further details; but two of peculiar interest, in preparation for textual publication, may be cited, namely: "Letters of Delegates to the Continental Congress relating to its transactions"; and "The American proceedings and debates in Parliament."

The Geophysical Laboratory.

The principal steps which have been necessary and in large degree preliminary in the development of the work of the Geophysical Laboratory are recounted with instructiv particularity by the Director in his report for the current year. They are the steps required to pass from a merely descriptiv knowledge of rock formation to a knowledge based on definit mesurements. Briefly stated, these steps are four in number, namely: provision for correct temperature determinations over the entire range involvd in the processes of rock formation; provision for like determinations of the chemical reactions of these processes; provision for precise microscopic, optical, and crystalografic mesurements; and provision for the quantitativ applications of high pressures to rock masses and rock constituents.

In supplying the desiderata just indicated for its own special work, the laboratory has alredy achievd results of prime importance also to many other fields of physical and chemical science. Thus, two contributions of great import to general physics and chemistry have been brought out during the past year. The first of these is a determinate extension of the scale of temperature mesures from about 300° C. to about 1600° C. This is a fitting supplement to the classic work on thermometry begun more than thirty years ago under the auspices of the International Bureau of Weights and Measures. It must take rank, in fact, with the fundamental advances in the technique of thermometry. The other contribution is a determination of the system of compounds which may arise in combinations of the three most important oxides entering into the composition of rocks, namely, silica, lime, and alumina. This system is of special economic interest, since it includes, among many other compounds, the hitherto much studied but baffling Portland cement. The complexity of the investigations requird to analyze this system is indicated by the facts that it involvs the interaction of fourteen minerals and the formation of sixteen ternary eutectics, or substances whose melting-points are lower than those of the primary constituents.

Many other important investigations are outlind in the Director's report and the productivity of the laboratory may be inferd from his citation and review of twenty-five publications emanating from the staff during the year. It is of interest to note in this connection that researches from the laboratory find redy access for prompt publication thru current journals both at home and abroad. Many of these papers have alredy been publisht in German as well as in English and arrangements have been made during the year to maintain this doubly effectiv mode of publication.

Six years ago, when the duties of the Presidency were assumed by the writer, he deemd it desirable to visit at the erliest opportunity all individuals pursuing researches under the auspices of the Institution. It soon developt, however, that a speedy accomplishment of this task would prove quite impracticable, and it became essential to adopt a much more restricted program for activities in this direction. Thus, while nearly all other departmental establishments of the Institution have been visited by the President prior to the past year, his first visit to the Tortugas Laboratory was not made until June, 1910. Having alredy entertaind very favorable, but somewhat indefinit, opinions concerning the wisdom of the choice of this locality for a marine laboratory, it is fitting to state that the extraordinary biological resources and the salubrity of the summer climate of the Tortugas group are so evident as to rouse the enthusiasm of any interested observer. As pointed out by the Director of the laboratory, the isolation even of these islands furnishes important advantages to the investigator. In brief, the favorable impressions gaind during the first visit in respect to the locality and in respect to the scientific spirit and possibilities of the establishment are only temperd by the present incapacity of the Institution to give more liberal financial support to this department of work.

Department of Marine Biology.

Two emergencies seriously affecting the department and calling for prompt action have arisen during the year. One is due partly to the gradual abandonment by the U. S. Navy of the supply depot and wireless station at Tortugas, thus rendering communication between Key West and the laboratory less certain and frequent than hitherto. The curtailment of this source of aid generously extended by the Navy to the laboratory during the past six years has forced upon the department the necessity of providing better independent transportation than that afforded by its best boat, the *Physalia*. One object, therefore, of the visit above referd to was to consider with the Director the best way to meet this urgent need. Accordingly plans and specifications for a 70-foot twin-screw boat were prepard during the summer; and on authorization by the Executiv Committee, at its meeting of October 18, 1910, a contract for the construction of this proposd vessel was let October 31, 1910, to the Miami Yacht and Machine Co., of Miami, Florida, with the expectation that the contract will be completed July next.

The other emergency arises from the damage to the laboratory caused by the hurricane of October 14-18, 1910. The extent of this damage is not definitly known at the present writing, but steps have been taken to get trustworthy details at the erliest practicable date, so that estimates of the expense requird to restore the building may be redy for submission to the Board of Trustees before their next meeting in December.

It is gratifying to note that the opportunities afforded for intensiv research by the laboratory are so highly appreciated that applications for its privileges are alredy more numerous than can be granted. Each year since its establishment additions have been made to its equipment and the Director

hopes that with some minor additions quarters may be found for fifteen or more investigators every summer. During the past season twelve associates, one collector, and one artist illustrator, in addition to the Director, carrid on work at the laboratory. Of the investigators, nine returned to continue work begun in previous years, while two of the other three expect to return in 1911. Many researches are in progress, therefore, as may be seen by reference to the full reports of the Director and his associates in the current Year Book.

Of the publications of the department during the year, special attention should be cald to the comprehensiv monograf in three quarto volumes by Dr. Mayer, on "The Medusæ of the World," issued as Publication No. 109 of the Institution. Two other volumes, Publications Nos. 132 and 133, containing shorter papers from the Director and associates of the laboratory, are now passing thru the press.

Department of Meridian Astrometry.

Capital progress has been made during the year in the large and exacting undertaking which this department has so successfully started. Work at the observatory in Argentina has gone forward at an unprecedented rate and with such a degree of thoroness and completeness as to give assurances that this part of the enterprise will be completed within the next year. Great credit is properly assignd by the Director to the zeal and the industry shown by the resident staff of the observatory in thus completing, within so short a time and without lowering the highest standards of precision, an unparalleld amount of observational work. The general success of this enterprise affords a forcible illustration of the superior effectiveness of a department of research which may proceed with its work intensivly in accordance with carefully prearranged plans and organization of effort.

While the supplementary observations of the positions of the stars are going forward in the southern hemisphere, arrangements for the final computations of these positions are proceeding at the Dudley Observatory; for the formidable task of observation must be followd by a still more formidable task of computation. Preliminary to the grand catalog of stellar positions projected by the department, there has been issued by the Institution during the past year, as Publication No. 115, a catalog of 6188 stars for the epoch 1900. This has alredy assumd first rank among catalogs of precision and the demand for it indicates that a second edition may be cald for before the larger catalog is completed. In response to a demand from other astronomers and in view of the needs of his own work, the Director has publisht also, thru the Dudley Observatory, a "List of 1059 standard stars for 1910."

Altho this laboratory has been occupied less than two years and is not yet fully equipt, it has alredy produced contributions of fundamental importance to our knowledge of the chemistry, physics, physiology, and pathology of nutrition. Its experience, like that of all the laboratories of the Institution, affords an impressiv demonstration of the productivity attainable by concentrated effort along determinate lines of research. Construction and instalation of additional equipment, the prosecution of investigations, and the publication of results have gone forward simultaneously during the year.

The Nutrition Laboratory.

One new calorimeter has been completed, another partly constructed, and various auxiliary apparatus for use with these and the erlier equipments have been supplied. Similarly, respiration apparatus for men, respiration apparatus for dogs, and many improvements in the calorimeter section of the laboratory have been made. Several pieces of apparatus have been acquird also by purchase abroad, and the efficiency of the machine shop has been improvd by the addition of a precision lathe.

The investigations under way at the laboratory and outlined in the Director's report are too numerous and too technical to permit further abstract or parafrase. It may suffice here, therefore, to cite one of the most important of these investigations in which decided progress has alredy been made, but which may yet require many years to complete, namely, the nature and meaning of metabolism in diabetes. In the researches on this recondite problem the Director has thus far had the good fortune to enlist the activ cooperation of Dr. Elliott P. Joslin, thru whose aid especially it has been possible to use the laboratory's apparatus in detaild observations and mesurements of a number of diabetic patients during the past two years.

The preliminary results of the research just referd to were regarded as so important as to justify prompt public announcement, and they have accordingly been printed during the year in Publication No. 136. Interest in the laboratory and its work is now so widespred that another volume, describing in detail the respiration calorimeters and their applications, by the Director and Mr.Thorne M. Carpenter, has been issued as Publication No. 123. Many shorter publications from members of the research staff have appeard during the year in current journals and in the proceedings of learned societies.

The rapid growth in equipment and facilities and the equally rapid progress in the production of capital results from the researches at this observatory are at once sources of surprise and gratification to the astronomical world. Work during the past year has gone on with little diminution of vigor, altho illness of the Director has forced him to relinquish his activities for a considerable portion of the time. He has recently gone abroad for a season and the departmental

The Solar Observatory.

report for the past year has been prepard by Mr. Walter S. Adams, now Acting Director of the Observatory.

The work of this establishment is now so extensiv and so varid that it is somewhat difficult to summarize even in its salient aspects. In addition to the observatory proper, with its four principal telescopes and much auxiliary equipment on Mount Wilson, there are the physical laboratory and the instrument shops at Pasadena, along with special divisions devoted to the work of computations and construction respectivly. To become conversant, therefore, with the complexity of activities of this department, one must read the somewhat lengthy but relativly condenst annual reports of the Director.

By way of equipment several large pieces of apparatus for the new tower telescope, for the 60-inch telescope, and for the 100-inch grinding machine have been made at the shops. The towers for the new 150-foot tower telescope, begun a year ago, are now finisht along with the well, 75 feet deep in the rock below, which forms a part of the telescope tube of this novel instrument, now essentially complete except for its spectroscopic attachments still under construction at the shops. Some preliminary trials made recently with this instrument indicate that it will fulfil the sanguin expectations entertaind in respect to its capacity.

At the time of the annual meeting of the Board of Trustees a year ago "The Monastery," a wooden building on Mount Wilson supplying quarters for the resident members of the observatory staff, was completely destroyd, along with a considerable number of books and other valuable property, by fire. This building has been replaced during the year in somewhat enlarged form by a reinforced concrete structure.

Progress has been made during the year in the details of designs for the proposed 100-inch or "Hooker" telescope, for which Mr. J. D. Hooker, of Los Angeles, made a substantial gift to the observatory some years ago. This work has been in charge of Professor Ritchey, whose construction of the 60-inch reflector has provd so signally successful. After repeated trials and failures to make a satisfactory disk the contracting firm at St. Gobain, France, have quite recently renewd the hope that a disk they now have annealing may meet the exacting requirements set by the astronomers.

Allusion has alredy been made in an erlier part of this report to the meeting of the International Union for Cooperation in Solar Research held at the observatory during the week of August 29 to September 4 of the current year. An outline of the proceedings of this meeting, which was of peculiar interest to the observatory staff, is given by the Acting Director at the end of his report. In spite of the difficulties of access to the observatory site, this meeting was regarded as the most important held by the Union. Opportunities were afforded the visiting astronomers and physicists to inspect the entire establishment and to test especially the efficiency of the

telescopic apparatus. Their appreciation of these opportunities and of the optical perfection of the telescopes, particularly of the 60-inch equatorial reflector, is a source of keen encouragement to the observatory staff.

Attention is invited to the interesting account given in the departmental report of the numerous investigations now under way at the observatory and in the physical laboratory at Pasadena. They are so effectivly summarized in this report that any restatement appears superfluous.

Department of Terrestrial Magnetism.

No department of research in the Institution is conducting work which is at once so obviously practical and so obviously theoretical as the work of the Department of Terrestrial Magnetism. Every one acquainted with the daily use of the compass in exploration, in surveying, and in navigation recognizes the practical utility of a magnetic survey of the erth. But those who recognize that any utilitarian results may come from a deeper knowledge of the erth's magnetism and its cosmic connections are at present very limited in number. Nevertheless, the history of science warrants a confident expectation that the latter results will ultimately prove to be of much greater value than the former.

The more striking events of the year in this department refer naturally to the non-magnetic ship *Carnegie*, which was off on her first cruise at the close of the previous fiscal year. She was then at Falmouth, England, where her determinations of the magnetic elements were compard with independent determinations made at the permanent magnetic observatory of that port. She proceeded thence, November 9, 1909, to Funchal, Madeira; thence to Hamilton, Bermuda; and thence, under tempestuous conditions which provd her seaworthiness, to Brooklyn, N. Y., where she arrivd February 17, 1910. Here she had her copper sheathing applied by the constructors, as requird by their contract, and was overhauld and refitted for a three years' circumnavigation cruise. It is a pleasant duty to report that in all essential respects this vessel has proved more effectiv than was anticipated. It has been demonstrated that even in rough weather the three magnetic elements (declination, dip, and intensity) may be determind with a precision little short of that attainable in a fixt observatory. Thus she was able to discover on her first cruise errors of unexpected magnitude in the best sailing charts of the north Atlantic, and she is certain to attain at least an equal degree of precision in all future ocean work. By crossings of her own tracks and by connections at all available ports having magnetic observatories it will be practicable to exclude the possibilities of any important errors in this work.

Similarly satisfactory progress has been made also in the land work of the department during the year. The expedition in Africa, from the Cape to Cairo, undertaken by Dr. Beattie and Professor Morrison as temporary

associates, was completed erly in the year, a total of 348 stations having been occupied. Mr. Pearson, field observer of the department, continued work in Turkey in the erly part of the year until relievd by Mr. Sligh, who extended the work to Palestine, Syria, Arabia, Mesopotamia, and the islands of Rhodes and Cyprus. Up to the end of July of this year these two observers had occupied a total of 47 stations. Another observer, Mr. Stewart, left Washington erly in June to begin extensiv work in South America, proceeding in the launch *El Imán*, provided especially for work along the Amazon and its tributaries. Additional observations are reported also from Canada and from various European countries in which initial determinations or instrumental comparisons have been made.

The offis work of the department has gone forward with corresponding productivity, the large volume of computations requird being kept closely up to date. The preparation for collectiv publication of data obtaind by the department on land and on sea is now well advanced, altho many of these data have been alredy furnisht for use by hydrografic offises and other national and international bureaus. Much critical attention must be devoted by the offis staff to the inspection and perfection of instruments and auxiliary appliances. By the aid of a skild mechanician and a shop now attacht to the department it has been practicable to attain a degree of instrumental perfection and a degree of economy in cost not hitherto equald in this kind of work.

Investigations of Research Associates.

About fifty research associates have carried on investigations under the auspices of the Institution during the past year, either by aid of grants made directly to the individuals concernd, or by aid of grants made to organizations like the American Schools at Athens and Rome, or by cooperation with our departments of research. In general, each of these associates has been in collaboration with one or more colleags or assistants, so that the total of those contributing to this work has been upwards of one hundred investigators. The range of their investigations embraces sixteen distinct fields of research, namely: archeology, astronomy, botany, chemistry, geology, geophysics, literature, mathematics, metallurgy, meteorology, paleontology, philology, physiology, political science, terrestrial magnetism, and zoology. Reference must be made, therefore, to the reports of individual investigators and to the general bibliografy, to be found in the current Year Book, for a fuller account of the fruitful activities in this branch of the Institution's work. It should be observd, however, that existing and prospectiv economic conditions, elsewhere referd to in this report, will probably require curtailment in this branch of work in the near future.

Classics of International Law.

The preliminary preparations for the publication of the Classics of International Law, such as the determination of the classics selected for publication and the designation of the individual editors, have been largely completed, and an erly appearance of some of the volumes may be confidently expected. The General Editor of the Series, Prof. James Brown Scott, furnishes the following memorandum with respect to the present status of this enterprise:

The text of Grotius' De Jure Belli Ac Pacis (1625) has been fotografically reproduced and the translator, Dr. J. D. Maguire, professor of Latin in the Catholic University of America, has alredy translated the Introduction and Books 1 and 2, as well as a considerable portion of the third and final book. He expresses the hope that the entire translation of the work will be completed by the end of this year. In that event the original text and translation will be redy for publication erly in 1911.

The Juris et Judicii Fecialis (1650) of Zouche has been fotografically reproduced and is redy for publication. It has been edited by Prof. Thomas Erskine Holland, until recently professor of International Law and Diplomacy in the University of Oxford, who has supplied an introduction to the text, a list of errata, and an index of authors cited; he has given the entire work careful supervision, including a translation of the text, by Mr. J. L. Brierly, of Lincoln's Inn, Barrister-at-Law, Fellow of All Souls College, and Lecturer of Trinity College, Oxford. It is probable that the text and translation of Zouche will appear erly in 1911.

The preparation of Ayala's De Jure et Officiis Bellicis et Disciplina Militari (1582) was intrusted to Dr. John Westlake, until recently professor of International Law in the University of Cambridge. He has completed the introduction to be prefaced to the original text, and a translation has been made, under Professor Westlake's direction, by Mr. John Pawley Bate, LL. D., Reader of Roman and International Law in the Inns of Court, London. Professor Westlake's introduction and the translation have been receivd by the Institution and the original text has been reproduced fotografically. It is probable, therefore, that the text and translation of this work will appear some time in 1911.

Prof. A. G. de Lapradelle, of the University of Paris, has undertaken the editorial supervision of Vattel's Droit des Gens (1758) and the text of the entire work has been reproduced fotografically. Professor de Lapradelle expected to have the introduction completed during the summer, but it has not yet been receivd. It will probably arrive, however, before the close of the year, and the Institution will be able to publish this masterpiece in the course of 1911.

In a letter dated October 13, 1910, the distinguished Dr. von Bar, professor in the University of Göttingen, states that he has completed the introductions to be prefaced to Rachel's De Jure Naturæ et Gentium (1676) and Textor's Synopsis Juris Gentium (1680). The texts of Rachel and Textor

have not yet been reproduced, but, since they are very short, this part of the work will require little time.

Dr. Georg Jellinek, professor of International Law at the University of Heidelberg, has undertaken the editing of the two masterpieces of Wolff, Jus Gentium Methodo Scientifica Pertractatum (1749) and Institutiones Juris Naturæ et Gentium (1750). His introductions to both of these works are completed, and they may be expected in the course of the current year. The texts in question have not yet been reproduced, but it is hoped that they may be completed during the coming year.

PUBLICATIONS.

Publications Authorized and Issued during the Year.

The publication of twenty-three volumes has been authorizd by the Executiv Committee at an aggregate estimated cost of $39,900. The following list gives the titles and names of the authors of publications issued during the year. It includes twenty-nine volumes with an aggregate of 3,274 octavo pages, 4,341 quarto pages, and one folio of 490 pages.

List of publications issued during the year.

Year Book, No. 8, 1909. Octavo, VII + 260 pages, 16 plates.
Index Medicus, Second Series, vol. 7, 1909. Octavo, 1,348 pages.
No. 53. Müller, W. Max. Egyptological Researches. In two volumes. Quarto.
Volume 2. Results of a Journey in 1906. Pages v + 188, 47 plates, 68 text figures.
No. 74. Sommer, H. Oskar. Vulgate Version of the Arthurian Romances. Edited from MSS. in the British Museum. In six volumes. Quarto.
Volume I. Lestoire del Saint Graal, 296 pages.
Volume II. Lestoire de Merlin, 466 pages.
Volume III. Le Livre de Lancelot del Lac, Part I, 430 pages.
No. 85. Hasse, Adelaide R. Index of Economic Material in the Documents of the States of the United States. Prepared for and under the direction of the Department of Economics and Sociology of the Carnegie Institution of Washington. Separate volume for each State. Quarto.
Kentucky (1792–1904), 452 pages.
Delaware (1789–1904), 137 pages.
No. 87. The California Earthquake of April 18, 1906. Report of the State Earthquake Investigation Commission, A. C. Lawson, Chairman. Quarto, two volumes and atlas.
Volume 2. The Mechanics of the Earthquake. By H. F. Reid. VIII + 192 pages, 2 plates, 62 text figures.
No. 96 (Part II). Barus, Carl. Condensation of Vapor as induced by Nuclei and by Ions. Report IV. Octavo, VIII + 84 pages, 21 text figures.
No. 100. Ward, William Hayes. The Seal Cylinders of Western Asia. Quarto, XXIX + 428 pages, 1,500 text figures.
No. 105. Lehmer, Derrick N. Factor Table for the First Ten Millions, containing the smallest factor of every number not divisible by 2, 3, 5, or 7, between the limits 0 and 10017000. Folio, XIV + 476 pages.
No. 108. Van Deman, Esther B. The Atrium Vestæ. Octavo, XII + 47 pages, 17 plates.
No. 109. Mayer, Alfred G. The Medusæ of the World. Quarto. In three volumes.
Volume I. The Hydromedusæ, pp. 1–230 + XV, plates 1–29, text figures 1–119.
Volume II. The Hydromedusæ (continued), pp. 231–498 + XV, plates 30–55, text figures 120–327.
Volume III. The Scyphomedusæ, pp. III + 499–735, plates 56–76, text figures 328–425.

No. 115. Boss, Lewis. Preliminary General Catalogue of 6,188 Stars for the Epoch 1900, including those visible to the naked eye and other well-determined Stars. Quarto, XXXVII + 345 pages.

No. 116. Reichert, Edward T., and Amos P. Brown. The Differentiation and Specificity of Corresponding Proteins and other Vital Substances in relation to Biological Classification and Organic Evolution: The Crystallography of Hemoglobins. Quarto, XIX + 338 pages, 100 plates, 411 text figures.

No. 119. Perrine, Charles D. Determination of the Solar Parallax from Photographs of Eros made with the Crossley Reflector of the Lick Observatory. Quarto, V + 98 pages, 1 plate, 2 text figures.

No. 121. Davenport, C. B. Inheritance of Characteristics in Domestic Fowl. (Paper No. 14, Station for Experimental Evolution.) Quarto, 100 pages, 12 colored plates.

No. 122. Johnson, Roswell H. Determinate Evolution in the Color Pattern of the Lady Beetles. (Paper No. 15. Station for Experimental Evolution.) Octavo, IV + 104 pages, 92 text figures.

No. 123. Benedict, Francis G., and Thorne M. Carpenter. Respiration Calorimeters for studying the Respiratory Exchange and Energy Transformations of Man. Octavo, VII + 102 pages, 32 figures.

No. 124. Robertson, James A. List of Documents in Spanish Archives relating to the History of the United States, which have been printed or of which transcripts are preserved in American Libraries. Octavo, XV + 368 pages.

No. 125. Richards, Theodore W., and H. H. Willard. Determinations of Atomic Weights. Octavo, IV + 113 pages, 4 text figures.

No. 126. Benedict, Francis G., and Thorne M. Carpenter. The Metabolism and Energy Transformations of Healthy Man during Rest. Octavo, VIII + 255 pages.

No. 129. MacDougal, D. T., and W. A. Cannon. The Conditions of Parasitism in Plants. Octavo, III + 60 pages, 2 text figures, 10 plates.

No. 135. Baxter, G. P., in collaboration with M. A. Hines, J. Hunt Wilson, F. B. Coffin, G. S. Tilley, Edward Mueller, R. H. Jesse, Jr., and Grinnell Jones. Researches upon the Atomic Weights of Cadmium, Manganese, Bromine, Lead, Arsenic, Iodine, Silver, etc. Octavo, VII + 185 pages, 5 text figures.

No. 136. Benedict, Francis G., and Elliott P. Joslin. Metabolism in Diabetes Melitus. Octavo, VII + 234 pages, 2 plates.

Pamflet, Issued on the Occasion of the Dedication of the Administration Building at Washington, December 13, 1909. Octavo, 32 pages, 1 plate, 20 figures.

Storage of Publications.

As fast as the steel shelving of the storage vaults of the Administration Building became available during the present year, steps were taken to collect and to arrange in safe and orderly condition the publications of the Institution, which have accumulated somewhat rapidly in recent years. These had been stored, chiefly in packing boxes, partly in the Bond Building and partly in the attic of the Geophysical Laboratory. They are now all catalogd, secured in dust-proof packages, and stackt so that they may be redily inspected and cared for. Since the walls of the vaults are impervious to moisture and since the moisture of the air within them may be controld by the heating plant, the volumes in storage may be considerd reasonably secure against the usual sources of damage and deterioration.

Sales of Publications and Value of Those on Hand.

The gross amounts receivd annually from sales of publications, including subscriptions to the Index Medicus, are shown in the fourth colum of the table on page 16 of this report. The amounts receivd from subscriptions to the Index Medicus, from the sales of Year Books, and from sales of all other publications, are shown separately in the following table for each year since the foundation of the Institution:

Table showing Sales of Publications.

Year.	Index Medicus.	Year Book.	Miscellaneous Books.
1903	$2,256.91	$29.25	.....
1904	2,370.47	52.85	$12.75
1905	2,562.76	44.75	431.44
1906	2,970.56	37.60	1,341.52
1907	3,676.71	56.50	2,292.89
1908	3,406.19	99.65	4,371.67
1909	4,821.85	73.01	6,287.21
1910	4,470.50	100.70	5,899.05
Total..	26,535.95	494.31	20,636.53

Altho the figures in this table show some degree of fluctuation, it seems safe to predict that the sales of miscellaneous publications especially will go on increasing for some years before reaching a maximum amount. In the meantime the reflectiv public is coming to understand that it is more rational for the Institution to offer its publications for sale at nominal prices than to attempt the unsatisfactory and wasteful task of a broadcast free distribution.

At the end of the fiscal year just closed there are on hand 69,763 volumes of miscellaneous publications and Year Books, having a sale value of $152,-776.55. There are also on hand 25,287 numbers, or the equivalent of about 2,000 volumes, of the Index Medicus, having a sale value of $11,725.25. The total value of publications now on hand is therefore $164,501.80.

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit at the annual meeting of the Board of Trustees a report for publication, and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the year 1909-1910.

During the fiscal year ending October 31, 1910, the Executive Committee held nine meetings. Printed reports of these meetings have been sent to the members of the Board of Trustees.

At the meeting of the Board of Trustees on December 14, 1909, Messrs. Mitchell, Parsons, and Welch were elected to succeed themselves as members of the Executive Committee for a term of three years.

Upon the adjournment of the Board of Trustees on December 14, 1909, the members of the Executive Committee met and organized by the election of Mr. Welch as Chairman for 1910, and by voting that Mr. Gilbert, Assistant Secretary of the Institution, act as Secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1909-1910, together with various recommendations and suggestions, and also an outline of suggested appropriations for the year 1911. The Executive Committee hereby approves the report of the President, and his recommendations, as the report and recommendations of the Committee.

The Executive Committee on October 18, 1910, voted to recommend to the Board of Trustees that the salary of the Director of each Department of the Institution, with the exception of the Department of Economics and Sociology, be $6,000 beginning January 1, 1911, and provision for this increase in salaries has been made in the President's recommendations for the budget of 1911.

The Chairman of the Board of Trustees, in accordance with the By-Laws of the Institution, notified the Committee, at the meeting of October 18, 1910, that he had designated The American Audit Company to audit the accounts of the Institution for the fiscal year ending October 31, 1910, and the report of this company is herewith submitted as a part of the report of the Executive Committee.

There are also submitted a financial statement and a statement of receipts and disbursements for the year, together with a statement of aggregate receipts and disbursements since the organization of the Institution on January 28, 1902.

Certain proposed amendments to the By-Laws, framed in accordance with the action of the Trustees at their last meeting, were approved by the Executive Committee at its meeting of May 16, 1910, and written notice of such proposed amendments has been forwarded to each member of the Board of Trustees.

It becomes the duty of the Executive Committee to report the death of Darius Ogden Mills, a former Trustee of the Institution, on January 3, 1910.

Three vacancies in the Board of Trustees will call for action at the coming annual meeting.

WILLIAM H. WELCH, *Chairman.*
JOHN S. BILLINGS.
CLEVELAND H. DODGE.
S. WEIR MITCHELL.
WM. BARCLAY PARSONS.
ELIHU ROOT.
CHARLES D. WALCOTT.
ROBERT S. WOODWARD.

December 12, 1910

Financial Statement, October 31, 1910.

	ASSETS.	LIABILITIES.
Endowment		$12,000,000
Reserve Fund:		
Administration Building Fund (balance due on contract)		2,045.39
Aggregate premium from sale of bonds		1,893.75
Insurance Fund and accrued interest		21,010
Bonds (original cost):		
U. S. Steel Corporation bonds, 5 per cent	$12,000,000	
$50,000 A., T. & S. Fe Ry. Co. 4 per cent 100-year gold bonds, due Oct. 1, 1995	50,056.25	
$50,000 L. S. and Mich. S. Ry. 4 per cent debenture bonds, due Sept. 1, 1928	48,222.22	
$50,000 C. Pacific First Refunding gold 4 per cent bonds, due Aug. 1, 1949	51,937.50	
Real Estate, Equipment, and Publications:		
Administration:		
Building, site, and equipment	312,307.93	
Publications:		
Stock on hand and outstanding accounts (Oct. 31, 1910)	165,359.06	
Department of Botanical Research (Sept. 30, 1910):		
Buildings, office, and library $23,477.29		
Apparatus 6,713.75		
Operating appliances 8,555.28		
	38,746.32	
Department of Experimental Evolution (Sept. 30, 1910):		
Buildings, office, and library 38,131.12		
Laboratory apparatus 4,095.37		
Operating appliances and grounds 15,860.03		
	58,086.52	
Geophysical Laboratory (Sept. 30, 1910):		
Building, library, operating appliances 110,712.61		
Laboratory apparatus 58,585.75		
Shop equipment 10,567.90		
	179,866.26	
Department of Marine Biology (Sept. 30, 1910):		
Vessels 12,712.55		
Buildings, docks, furniture, and library 9,903.58		
Apparatus and instruments 1,741.02		
	24,357.15	
Department of Meridian Astrometry (June 30, 1910):		
Buildings and operating appliances 13,518.90		
Apparatus and instruments 2,394.34		
	15,913.24	
Nutrition Laboratory (Sept. 30, 1910):		
Building and office 108,492.60		
Laboratory apparatus 10,218.69		
Shop equipment 1,895.83		
	120,607.12	
Solar Observatory (Aug. 31, 1910):		
Buildings, grounds, road, and telephone line 113,328.52		
Shop equipment 18,953.25		
Instruments 265,888.95		
Furniture and operative appliances 40,147.50		
Hooker telescope 37,404.14		
	475,722.36	
Carried forward	13,541,181.93	12,024,949.14

Financial Statement, October 31, 1910—continued.

Real estate, Equipment, and Publications—Continued.			
Brought forward		$13,541,181.93	$12,024,949.14
Department of Terrestrial Magnetism (Sept. 30, 1910):			
Office	4,250.83		
Instruments	24,410.19		
Vessel and ocean equipment	116,976.57		
Land equipment	4,236.82		
		149,874.41	
Property Investment (aggregate cost)			1,540,840.37
Grants:			
Large			119,967.56
Minor			21,167.87
Research Associates and Assistants			7,853.78
Publication			68,652.34
Administration			14,553.80
Cash:			
In banks		132,749.55	
Stamps and petty cash fund		300	
Unappropriated Fund			26,121.03
		13,824,105.89	13,824,105.89

Statement of Receipts and Disbursements from November 1, 1909, to October 31, 1910, Inclusive.

RECEIPTS.

INTEREST:		
U. S. Steel Corp. bonds	$600,000	
A., T. & S. Fe Ry. "	2,483.34	
Central Pacific "	2,000	
L. S. and Mich. S. "	2,000	
Deposits in banks	3,939.44	
		$610,422.78
SALES OF PUBLICATIONS:		
Index Medicus	4,470.50	
Year Book	100.70	
Miscellaneous Books	5,899.05	
		10,470.25
REFUND ON GRANTS:		
Grant No. 400	144.76	
Grant No. 290	129.69	
Grant No. 543	116.66	
Grant No. 604	3.30	
Grant No. 535	74.88	
Grant No. 620	850	
		1,319.29
MISCELLANEOUS:		
Sale of A., T. & S. Fe bonds	49,500	
Sale of paper	345.65	
Sale of separates	22.15	
Refund, cost of sidewalk, sales of junk	94.18	
Refund, insurance	4,717	
Refund, shipping	53.47	
		54,732.45
		676,944.77
Balance from last report to Trustees, Oct. 30, 1909		118,178.57
		795,123.34

DISBURSEMENTS.

INVESTMENT:		
Building (administration)		$57,889.15
GRANTS:		
Large	$437,941.40	
Minor	47,565.94	
Research associates	25,898.69	
		511,406.03
Publication		49,067
ADMINISTRATION:		
Trustees	4,665.67	
Executive Committee	1,139.54	
Salaries	24,802.50	
Publication shipping expenses	4,347.23	
Insurance and surety	108.90	
Fuel, light, telephone	1,123.34	
Operating equipment	748.60	
Stationery	338.14	
Postage, express, etc	603.76	
Printing	* 2,781.44	
Building, grounds, supplies, and repairs	2,446.27	
Office supplies and petty expenses	906.22	
		44,011.61
		662,373.79
CASH IN BANKS:		
U. S. Trust Co., N. Y.	122,815.08	
National City Bank, N. Y.	7,837.12	
American S. & T. Co., D. C.	2,097.35	
		132,749.55
		795,123.34

* Including Year Book for 1909.

Statement of Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1910.

RECEIPTS.

INTEREST:		
U. S. Steel Corp. bonds	$4,500,000	
A., T. & S. Fe Ry. "	27,483.34	
N. Pac. Ry. Co. "	23,055.55	
N. P. Gt. N. "	9,500	
Central Pacific "	12,000	
L. S. and Mich. S. "	14,000	
Deposits in banks	71,671.28	
		$4,657,710.17
SALES OF PUBLICATIONS:		
Index Medicus	26,535.95	
Year Book	494.31	
Miscellaneous books	20,636.53	
		47,666.79
REFUND ON GRANTS		10,000.23
MISCELLANEOUS:		
Organization	1,825.52	
Sale of furniture	69	
Gas deposit	5.36	
Postage, express, and travel	53.30	
Printing and paper	1,302.54	
Sale of metal cuts	48.30	
Sale of separates	22.15	
Refund, shipping	53.47	
Refund, cost of sidewalk, sales of junk	96.62	
Refund, insurance	4,717	
		8,193.26
SALE OF BONDS:		
N. Pac. Gt. Nor.	48,000	
Northern Pacific	102,750	
A., T. & S. Fe	49,500	
		200,250
		4,923,820.45

DISBURSEMENTS.

INVESTMENT:		
Bonds	$348,572.22	
Administration Bldg. and site	307,870.30	
		$656,442.52
GRANTS:		
Large	2,583,677.55	
Minor	717,067.57	
Research Associates and Assistants.	* 181,136.71	
		3,481,881.83
PUBLICATION		281,223.96
ADMINISTRATION:		
Trustees	14,625.16	
Executive Committee	12,509.93	
Honorariums to advisers	17,319.81	
Salaries	225,813.03	
Publication shipping expenses	4,347.23	
Insurance and surety	2,683.92	
Rent and fuel	26,505.04	
Operating equipment	7,010.98	
Stationery	11,451.25	
Postage and express	18,059.89	
Printing	† 20,118.81	
Building, supplies, and repairs	2,446.27	
Office supplies and petty expenses	906.22	
Organization	1,825.52	
Plans and option	5,166.46	
Seal	555.60	
Miscellaneous	70.23	
		371,415.35
REFUND		107.24
		4,791,070.90
CASH IN BANKS		132,749.55
		4,923,820.45

* Including Special Grants of 1904, 1905 ($37,498.84).
† Including Year Books.

REPORT OF AUDITOR.

WASHINGTON, D. C., *December 6, 1910.*

The Executive Committee, Carnegie Institution of Washington:

GENTLEMEN: The books and accounts of the Carnegie Institution of Washington have been audited by us from November 1, 1909, to October 31, 1910, by authority of the Chairman of the Board of Trustees.

We did not, however, audit the books of the various Departments, as that is done by the Bursar and his associates, but we did verify the totals as carried from the subsidiary books to the general books.

The income from the Endowment Fund and from Investments has been duly accounted for and the expenditures have been regularly authorized, and are supported by proper vouchers.

On Tuesday, December 6, 1910, the undersigned, Mr. Otto Luebkert, in company with the Chairman of the Board of Trustees, attended at the vaults of the Hudson Trust Company, Hoboken, N. J., and examined the bonds of the Endowment Fund, finding same on hand and in proper order.

On Friday, November 18, 1910, Mr. Luebkert, in company with the Bursar, Mr. John L. Wirt, and the Assistant Secretary, Mr. W. M. Gilbert, visited the vaults of The American Security and Trust Company, Washington, D. C., and examined and found correct and in good order the securities comprising the Investment account.

Respectfully submitted,

THE AMERICAN AUDIT COMPANY,
By OTTO LUEBKERT, *Resident Vice-President.*

Approved:
F. W. LAFRENTZ, *President.*

[Seal of the American Audit Company of New York.]

Attest:
A. F. LAFRENTZ, *for Secretary.*

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK ACCOMPLISHED BY GRANTEES AND ASSOCIATES.

Under this heading it is sought to include the titles of all publications bearing upon work done under grants from the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 32–33). The following list has been made as complete as possible, and in some cases titles may be included which have only an indirect connection with grants from the Institution:

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REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1910, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.*

D. T. MacDougal, Director.

The record of the Department for the year shows the completion of some important researches, such as those concerned with the conditions of parasitism in plants, root-habits of desert plants, the water-balance of succulents, the organization of new work in climatology with the cooperation of Dr. Ellsworth Huntington, the formation of plans for dealing with problems in physiology by chemical methods under Dr. H. A. Spoehr, and the successful prosecution of researches on various correlated topics as described in the following paragraphs.

THE VEGETATION OF THE SALTON BASIN.

The general mode of procedure in the revegetation of the bared strands and emersed islands of the Salton Sea having now been determined, a closer analysis of the conditions is being made by physical and chemical methods.

The changing constitution of the water is clearly illustrated by the following data furnished by Dr. W. H. Ross, who, in consultation with Prof. R. H. Forbes, has made careful annual analyses of the waters from samples taken early in June at the same location. The third complete analysis of the water, together with the results of the two previous analyses, are given.

Composition of Salton Sea water.

	Parts in 100,000.		
	June 3, 1907.	May 25, 1908.	June 8, 1909.
Total solids (dried at 110° C.) plus water of occlusion and hydration	364.80	437.20	519.40
Water of occlusion and hydration	.....	.....	17.50
Sodium (Na)	111.05	134.26	160.33
Potassium (K)	2.29	2.78	3.24
Calcium (Ca)	9.95	11.87	12.70
Magnesium (Mg)	6.43	7.63	8.96
Aluminum (Al)	0.030	0.35	0.62
Iron (Fe)	0.005	0.006	0.010
Manganese (Mn)	None	None	None
Zinc (Zn)	None	None	None
Lead (Pb)	None	None	None
Copper (Cu)	.....	.....	Trace
Lithium (Li)	Trace	Tr. 0.013	0.017
Chlorine (Cl)	169.75	204.05	240.90
Sulphuric (SO_4)	47.60	56.74	65.87
Carbonic (CO_3)	6.58	7.66	7.34
Silicic (SiO_4)	1.41	1.43	1.59
Phosphoric (PO_4)	0.009	0.011	0.01
Nitric (NO_3)	0.18	0.20	None
Nitrous (NO_2)	None	Trace	0.0006
Oxygen consumed	0.093	0.059	0.068
Boric acid	.....	Trace	Trace

From the table it is seen that the variation in concentration of the constituents during the past year is not as uniform as for the preceding year. Thus, while the concentration of the sodium chloride and of the water as a whole has increased about 18 per cent since 1908, the amount of carbonates

* Situated at Tucson, Arizona. Grant No. 599. $34,728 for investigations and maintenance during 1910. (For previous reports see Year Books Nos. 2–8.)

present has, on the contrary, decreased. The quantity of calcium present has increased only 7 per cent over the preceding year instead of 18 per cent, as might have been expected. The difference between these two values is more than equivalent to the deficiency found for carbonates. It therefore follows that a precipitation of calcium carbonate must have taken place during the past year. The increase in sulphates is only 16 per cent, and since the deficiency of calcium is a little more than equivalent to the amount by which the carbonates fall short of the average increase in concentration, it would seem as though a small amount of calcium sulphate has also been precipitated. This may have resulted, however, from a change in relative concentration due to seepage-water from the Colorado River and to local storm-waters. On the other hand, there has taken place a marked increase in the quantity of iron and aluminum present, amounting to about 75 per cent for each.

The determination of nitrates in the water for the present year was made immediately after it had been received at the laboratory. In a short time, however, the nitrates had entirely disappeared. As samples collected the two previous years were allowed to stand for a time before being analyzed, it is possible that nitrates may have been originally present in these samples also, in small amounts. The increase in nitrates for 1908 over 1907 amounted to only 11 per cent, instead of the average increase of 20 per cent, which shows that they had undergone a partial change in composition; while during the past year they have entirely disappeared. The cause of this disappearance of the nitrates is not apparent at present. The large value found for silica in the first analysis may have been due to the action of the water on the glass of the carboy in which the sample was collected.

In order to interpret the action of the water upon organisms living in it, and to prepare for a more skilled study of the lake in its lower stages, Prof. G. J. Peirce, of Stanford University, has undertaken a study of the behavior of some ponds on the flat shore of San Francisco Bay, into which water is pumped from the bay for the manufacture of salt. The water rapidly evaporates during the dry season, leaving an accumulation of salt on the bottom and sides of these ponds, and even more or less of a crust on parts of the surface of the mother-liquor.

From a minimum specific gravity of 1.06 in the rainy season, the concentration rises in the course of three or four months, until the specific gravity reaches 1.225. At this concentration much common salt has crystallized out, leaving a mother-liquor proportionally much richer in calcium and magnesium salts than the bay water.

A small crustacean (an *Artemia* described by Professor Kellogg in Science) and the larvæ of some flies are the only animals living, in large numbers at least, in these brines. There are, however, a very considerable number of plants, without exception unicellular, which live in the brines at all concentrations. These plants are bacteria of various sorts, chromogenic and other, and Chlamydomonas-like algæ, both green and brown, which are found in various stages of their existence at different times in these ponds. These

are now growing in pure culture in solid and liquid media in the botanical laboratory of Stanford University, and their behavior, with relation to the changes in their environment, is being studied. A study of these organisms, living in brines sufficiently concentrated to serve as preservatives for highly putrescible substances, should throw a certain amount of light on the osmotic relations of plants and animals to their surroundings; and the rapid changes through which these organisms successfully pass, without apparent injury, must modify our notions of the adaptability of living things.

A series of soil examinations of exposed strands was made by Mr. E. E. Free, of the Bureau of Soils of the U. S. Department of Agriculture. These studies have been made on the assumption that the distribution and movement of plants thereon might be influenced to an important degree by the local character of the soils and especially by variations in the amount of soluble salts ("alkali") which they contain. Detailed examinations have therefore been made of the soil and alkali conditions on the waste sand-terraces near Travertine Point, the sandy beaches between Salton Station and the mouth of Salt Creek, the net beaches on the two larger islands, and the broad dry plain southwest of Imperial Junction. The studies of the last locality have been especially careful and detailed. The results show that the distribution of the excessive salt on a single beach is in general quite uniform, though different localities may differ widely from one another as a result of differences in soil-texture or underground conditions. The local distribution of vegetation on any particular beach is not, therefore, a function of the salt-content of the soil. The soil-texture and minor features of the topography (especially the drainage-lines) have, however, an important influence on this distribution, mainly because of their control of water-supply.

Visits to the shores of the lake were made in June and October for the purpose of following the variations in the vegetation of the strands. An examination of the steep slopes rising from near the present level of the water to near the highest ancient level disclosed 83 strands or beaches. Some of these were especially well marked, and these were seen at high levels, indicating that the basin has been filled to sea-level, or nearly so, within a few hundred years, and perhaps more than once recently.

INVESTIGATIONS.

Climatology of American Deserts (by Dr. Ellsworth Huntington):

During the spring of 1910 Professor Ellsworth Huntington, of Yale University, cooperated with the Desert Laboratory in a geographic study of the deserts of southern Arizona and northern Mexico, as compared with those of Asia. The chief problems were naturally climatic. Field-work was carried on during March, April, and May. From Tucson trips were made in all directions, in company with Dr. MacDougal or Mr. Sykes.

Two river systems, each nearly 200 miles long, were selected for comparative study, namely, the Santa Cruz, running northward past Tucson to the

Gila, and the Asuncion, whose two branches, the Altar and Magdalena, head near the Santa Cruz and flow southwestward through northwestern Mexico to the Gulf of Mexico. The subjects to which attention was chiefly devoted were, first, the relation of the climate of the country (with its twofold rainy season in winter and in summer) to the climatic zones of the earth as a whole; second, the length of time that arid conditions have endured and the effect of prolonged aridity upon topography; third, the effect of changes of climate upon topography; and fourth, the climatic history of the country from the Glacial period to the present time. The last subject proved most fruitful. It involved, among other matters, a study of such diverse subjects as the nature of the climate of Arizona during the Glacial period; the action of floods and the origin of the alluvial terraces found along all the rivers; the traces of a highly civilized and unexpectedly dense pre-Indian population, not only in the river valleys now inhabited, but in scores of places now uninhabitable; and the economic condition of the Indian before the coming of the white man.

At the end of the field season a general view of southern Arizona was obtained by a ride of 370 miles from Tucson westward to Yuma by way of Phœnix. This was followed by a few days devoted to a study of the peculiar features of the Salton Sea, especially its abandoned strands, both old and new. Throughout the entire season it was found that, although the deserts of southern Arizona differ markedly from those of most parts of Asia in certain botanical features, such as the occurrence of cacti and the surprisingly large number of trees and bushes in proportion to the rainfall, but there is remarkable agreement as to the topographic features and as to evidences of changes of climate.

Evaporation and Soil Moisture (by Dr. B. E. Livingston):

The study of evaporation and that of soil moisture has been continued. Several improvements have been made in the manipulation of the porous cup-atmometer, and an entirely new arrangement has been perfected whereby the error due to entrance of rain into the instrument is avoided. In the relation of plant activity to soil-moisture, several principles have been developed.

Dr. W. H. Brown has been employed as assistant in this work for the summer of 1910.

The problem of the physics of plant transpiration has been somewhat further simplified by experimental analysis, and considerable has been accomplished on the relation between this function and the intensity of sunlight. In this connection, a new integrating heliometer has been devised, which promises to be as valuable in studies on the relation of transpiration to solar radiation as has been the atmometer in those on the relation of transpiration to the evaporating power of the air.

The studies of Professor Livingston and Dr. Shreve, on the relations between the climatological factors and plant distribution in the United States, which have been in progress for several years, are now nearing completion and will soon be ready for publication.

Mrs. G. J. Livingston's Annotated Bibliography of Evaporation has now been completely published in the Monthly Weather Review, and separate reprints have been issued.

Conditions of Parasitism (by Dr. D. T. MacDougal and Dr. W. A. Cannon):

The long series of experiments upon this subject show that it is possible to establish regenerated cuttings of a number of species in a dependent nutritive relation with the bodies of enforced host-plants.

Arrangements of xeno-parasitism were made which endured for two seasons or more. The xeno-parasite formed roots which penetrated the tissues of the host in some instances, while in other cases absorption occurred through the epidermal tissues of the submerged bases of the inserted slips. The facts at hand do not warrant any conclusion as to the significance of morphological features in the assumption of nutritive relations between two seed-plants.

The development displayed by xeno-parasites was in all instances less than that of similar shoots autophytically nourished. The atrophy of the shoot characteristics of parasites was thus displayed as an immediate response to dependent nutrition. In addition to manifestations which might be classed as direct responses, the etiolated shoots of *Opuntia* exhibited striking autonomic movements not attributable to inequalities of growth. These movements appear to be caused by a rhythmic inequality of turgidity in the outer parenchymatous tissues of the stems, which undergo changes simulating decortication. The zones of curvatures producing the movements moved up and down the stems from base to apex in a period of about 72 hours.

Successful xeno-parasitism is dependent in the first place upon the superior osmotic activity of the parasitic member of the nutritive couple, although not all pairs of plants sustaining such inequality are capable of becoming host and dependent, and other features act as limiting factors of minor importance. The proportion of salts dissolved in the sap of the experimental plants and the osmotic activity as indicated by freezing-point tests undergo wide seasonal variations, as a result of which a xeno-parasite may maintain itself upon a host during the period of greatest turgidity of the latter and be unable to withdraw material from it during the drier season, when the sap of the host is of a relatively greater concentration. The general conditions which govern the origination of parasitism are thus so well apprehended that, given any two plants, knowledge of their capability for entering into a nutritive couple may be put in the form of an algebraic equation, the reduction of which would indicate with some certainty the possibility of their adhesion.

The unceasing distributional movements of plants would operate to bring under test conditions a large number of pairs of species, and it seems quite reasonable that new parasitic unions are being constantly formed in almost all kinds of habitats. This fact might escape detection by ordinary methods of observation almost indefinitely. The detailed description of the investigation of the entire problem is given in Publication No. 129, recently issued.

Alterations in Heredity Induced by Ovarial Treatment (by Dr. D. T. MacDougal):

The methods previously described have been extended to cover a wide range of species and with the use of additional reagents. A large number of progeny derived from treated ovaries are under observation, but no new announcement of results may be safely made. So far, derivatives in *Oenothera, Raimannia,* and *Penstemon* have been found and tested, while aberrant individuals in *Echinocereus* (formerly *Cereus*) have been secured. The new form in *Oenothera* has been found to be normal, self-maintaining, and persistently different from the parent.

Acclimatization: the Inductive Influence of Climatic Complexes upon Organisms (by Dr. D. T. MacDougal):

A large number of selected plants are being grown in the plantations at the Desert Laboratory, in the Santa Catalina Mountains, Arizona, and at Carmel, California, and somatic alterations are being induced under conditions suggestive of the actuating causes. The heritability of such changes and exact determinations of the reactions constituting the alterations are being carried out.

The Water-balance of Succulents (by Dr. D. T. MacDougal):

An extensive series of measurements of massive cacti, chiefly *in situ,* was carried out by Mrs. E. S. Spalding, and an equally extensive series of weighings of other plants was made by D. T. MacDougal, for the purpose of determining the part played by the water-balance in the growth and survival of these plants. A sahuaro (*Carnegiea*) 18 feet high holds nearly 200 gallons of water in its cylindrical trunk; the depletion and repletion of this water-balance takes place very rapidly and is influenced by sunlight, temperature, etc., in such manner as to be accompanied by some striking changes in form and size.

The presence of a great surplus of water in all parts of the plant has one singular consequence in the matter of the survival of living branches on dead trunks. The trunk may die and decay quickly by a black-rotting process which leaves the bare woody skeleton holding aloft the green branches, which are a few inches in thickness and may be several feet long. These branches may survive for a year, during which time they produce flowers as well as fruit. Whole and uninjured individuals of cacti may carry on some growth and live for two or three years upon their accumulated balance of water, while other species are known which carry sufficient surplus to meet their needs for ten or fifteen or perhaps twenty-five years.

The rate of loss of plants exposed in the open may be as much as four to eight times that of plants in inclosed but well-ventilated rooms, in which the direct action of the wind and sun are eliminated. This is apparent even when the plants tested in the shade were much larger than those in the open.

Observations on a number of specimens show that some gain in weight may be expected in small specimens of *Echinocactus* detached and kept in

well-ventilated rooms during January and December. This gain may be attributed to hygroscopic absorption of the dead spines. A small plant which had been desiccated for two years, when put in a dark room with equable temperature at about 60° F., with the relative humidity 80 to 90 per cent during February 1910, gained 2 grams in 10 days, and the same plant also increased its weight 4 grams in 24 days in 1909, during the first year of its desiccation. It is to be pointed out that the water taken up in this manner could be of no practical use to the plant, since the fluid would be held so tenaciously by the tissues of the dead spines that it could not be withdrawn by the osmotic activity of the living cells.

An inspection of the proportions of organic material and ash shows no relative variation in the sap of plants in which the supply of water had been partially depleted by desiccation. The total solids in the juice of a turgid *Echinocactus* amount to 2.692 grams per 100 c.c., of which the organic matter is 1.320 and the ash 0.772. The total solids in a desiccated specimen amounted to 7.060, of which 4.060 were organic and 3.0 ash. The general concentration had been increased in the ratio of 2 to 7, the concentration of organic matter from 1.3 to 4, and the concentration of the ash as 1 to 3. The total solids dissolved in the sap of a turgid *Carnegiea* amounts to 3.4 parts in a hundred, of which 2.4 are organic material and 1 ash. In the desiccated plant the dissolved solids amount to 9.6 parts in 100, of which 6.8 are organic and 2.8 ash. The general concentration was as 3.4 to 9.6, the concentration of organic material as 2.4 to 6.8, and of the ash as 1 to 2.8.

An examination of the chemistry of these forms might probably lead to results of value in the interpretation of their development. The cacti of the Tucson region, and probably all of these forms, are rich in calcium carried in solution in the sap as an accident of its occurrence in abundance in the soil. The sap shows a high degree of osmotic activity, ranging from 5 to 12 atmospheres in various species in a state of maximum turgidity, to perhaps twice this pressure when the water-balance is depleted. Furthermore, these plants, especially the halophytes, are known to be capable of an accommodative reaction, by which the osmotic pressure may be automatically increased in response to the increased concentration of the soil solutions. (See Publication No. 141.)

The Root-habits of Desert Plants (by Dr. W. A. Cannon):

A general résumé of the investigations upon the root-habits of plants in the vicinity of the Desert Laboratory has been made in Publication No. 131, and Dr. Cannon is now carrying on observations of similar purpose and scope upon the vegetation of Algeria and along the Nile in Egypt. Of the many important generalizations now sustained by results at hand, a few of the more obvious are as follows:

The root-systems of the rapidly-growing summer annuals of the desert are different from those of winter annuals, in showing a fuller development

of all components, but neither type penetrates the soil to a greater depth than 20 cm. (8 inches). Perennials have three types of roots, namely, the generalized type, with the tap root and the laterals both well developed, and the specialized forms of which one type has a prominent tap root and the other prominent laterals. *Covillea tridentata* and *Prosopis velutina* are representatives of plants with generalized roots, while *Kœberlinia spinosa* and a few other plants have specialized roots of the second type.

The roots of perennials growing on Tumamoc Hill and on the bajada do not penetrate as a rule more deeply than 30 cm., the depth of the available soil; while those on the flood-plains attain a depth of 2 to 5 meters.

The most shallowly rooted perennials observed were *Opuntia arbuscula* (whose roots frequently do not lie more than 2 cm. below the surface) and *Echinocactus wislizeni.* The arborescent opuntias have roots which approach the generalized type.

Most cacti have two divisions to the root-system: an anchoring and an absorbing system.

Fleshiness in the roots of the opuntias is a condition resulting directly from an abundant supply of water; this is true of young plants also. Whether some species exhibit greater tendency toward fleshiness than others was not determined. A similar reaction was seen in *Brodiæa capitata.*

Perennials with the generalized type of root-system have the widest local distribution, and those with a pronounced development of the tap root have the most limited distribution. Plants with laterals well developed, the cacti especially, are most abundant on bajadas or detrital slopes, as on Tumamoc Hill, where the soil is shallow, and occur seldom on the flood-plains.

Germination and Establishment of Desert Perennials (by Dr. F. Shreve):

Laboratory experiments have been conducted to determine the best conditions of temperature and soil-moisture for the germination of a selected group of desert perennials. All the forms used germinate at the higher temperatures of the summer growing-season, and it is found, in general, that the sclerophyllous species germinate at lower percentages of soil-moisture than do the succulents. The development of the root-system of the seedling and the changes in minimum water requirement with advancing age have been tested with the result that atmospheric factors are found to be quite as important as those of the soil in determining the behavior of seedlings. Further investigations have been carried into the field, where germination, growth, and fate of seedlings have been followed under uncontrolled conditions, simultaneously with the measurement of the atmospheric and soil conditions to which they are subjected. Striking differences have been found in the manner of establishment of the different classes of perennials, and survival has been found due not so much to chance variation in the seedlings as to small differences in the immediate environment of different individuals.

Vital Statistics of Desert Plants (by Dr. F. Shreve):

Statistical work has been undertaken with the giant cactus (*Carnegiea*), palo verde (*Parkinsonia*), and ocotillo (*Fouquieria*), with a view to determining the relative numerical proportions of groups of different ages to the total population. Data are being secured which indicate the character and direction of the changes in the population of these species, and through them indicate the secular changes which are going on in the make-up of the vegetation as a whole. The work indicates a diminution in the succulents and an increase in the sclerophyllous perennials on the clay soil of the Desert Laboratory domain.

Vegetation in the Santa Catalina Mountains (by Dr. F. Shreve):

A study of the climatology and vegetation of the Santa Catalina Mountains is being prosecuted in connection with the acclimatization work previously inaugurated by Dr. MacDougal. An aggregate of several weeks of observational work has been done during the summer of 1910, with a view of determining the vertical limits of certain common species in relation to slope-exposure and soil-conditions. The beginnings have been made of an attempt to establish certain native species above their natural limits in order to determine what phase of the climatic complex is most potent in limiting the vertical range. A digest has been made of the climatological records which have been accumulating for four years from the mountain plantations and the intermediate stations. The results have been a determination of the rate of shortening of the growing-season with increase of altitude and the determination of certain principles with regard to the zonal differences in temperature, rainfall, and evaporation conditions.

Physiology of the Hymenophyllaceæ (by Dr. F. Shreve):

Work on the Hymenophyllaceæ carried out in Jamaica in 1909 has been completed and the results prepared for publication. This markedly hygrophilous group is shown to have developed several epiphytic species, which are relatively xerophilous, through the ability of their protoplasts to withstand the loss of water from their sap-cavities, in which respect they resemble in some degree the xerophilous ferns of the desert.

Physiological Plant-geography of the Jamaican Rain-Forests (by Dr. F. Shreve):

The observational and experimental work carried on at Cinchona, Jamaica, in the latter part of 1909 is being collated and prepared for publication.

Vegetation and Climate of the United States (by Dr. F. Shreve):

In collaboration with Dr. Livingston, studies are being continued on the distribution of the plant formations of the United States and on the distribution of particular physiological types of plants with respect to the distribution of the climatic factors inducing them.

COOPERATIVE ARRANGEMENTS.

Influence of Environic Factors on the Fruiting of Dictyota (by Dr. W. D. Hoyt):

The fruiting of *Dictyota dichotoma* was studied at Naples during March and April, 1910. As was previously observed by Lewis, the sexual plants of this region were found to produce their crops at fortnightly intervals, agreeing in this respect with the plants of this species on the coasts of Wales and England and differing from the plants on the coast of North California; but the period during which these crops are borne at Naples differs from that of other localities.

A comparison of *Dictyota* at Naples with plants of the same species at Beaufort, North Carolina, involving the size of the plants, the relative proportion of tetrasporic and sexual plants, the fruiting of the tetrasporic plants, the time taken for a sexual crop to mature, the uniformity of the sexual crop, and the behavior of the vegetative cells of the sexual plants during fruiting shows that in all these respects the plants at Naples more nearly resemble specimens of *Dictyota* from Jamaica than they do those of the same species at Beaufort. An effort is being made to obtain plants of this species from other regions for comparison with those already studied.

A study of the liberation of the eggs and tetraspores shows that as there is a definite interval during which the crops of sexual cells is produced, while the tetraspores are borne throughout the month, so there is a definite hour during which the eggs are discharged while the tetraspores are discharged throughout the day.

The Influence of Environmental Factors upon Beetles in Pure Lines and in Hybridization (by Prof. W. L. Tower):

The investigations of Prof. W. L. Tower, of the University of Chicago, upon the reaction of the chrysomelid beetles to environmental or climatic conditions have been in charge of Mr. J. B. Breitenbecher during the season 1910. Additional cultures have been organized and a system of calibration of climatic factors inaugurated for the purpose of exact determination of the nature of the reactions of the beetles to the unaccustomed conditions. Because of the enforced absence of Professor Tower during the year, a summary of actual progress can not be given.

The Cactus Flora of the Sonoran Desert (by Dr. J. N. Rose):

Exploration was carried on in western Texas, southern New Mexico, and southeastern Arizona, and extended along the Mexican branch of the Southern Pacific from Hermosillo to Acaponeta.

About 10,000 specimens, representing 3,000 numbers, were collected. Although the expedition was a general one, it was chiefly devoted to the study of the Cactaceæ to that region. The most conspicuous plants in the landscape everywhere were the giant cacti, which form great forests extending for hundreds of miles up and down the west coast of Mexico. Of these *Car-*

negiea gigantea was especially conspicuous, and its southern geographical limits were more definitely fixed than heretofore. This species was traced as far south as the Yaqui River in southern Sonora. *Pachycereus pringlei,* another of these giant cacti, was very common about Guaymas, which seems to be near the southern limit of the species. The most striking and by far the most abundant of these giant cacti is *Pachycereus pecten-aboriginum,* which was observed from Guaymas to Acaponeta, a distance of about 500 miles, extending in a broad band 100 miles broad east and west. *Lemaireocereus thurberi* extends from southern Arizona as far south as Culiacan. South of Guaymas this species is very abundant and assumes much larger dimensions than in its northern range.

Four species of giant *Echinocactus,* usually called visnaga or barrel cactus, were observed on the trip. Several of the species are extensively used in making a Mexican candy. Numerous species of *Opuntia, Mamillaria,* and *Cereus* were collected and studied in the field.

MISCELLANEOUS.

The facilities of the Desert Laboratory were granted to Dr. W. H. Brown, research fellow of Johns Hopkins University, in September 1910, for one year, for the purpose of carrying on some work on problems in soil-moisture and transpiration.

Mr. J. G. Brown, Associate Professor in Botany of the University of Arizona, has carried on some work on morphology of cacti at the Desert Laboratory since January 1910, and has also given some assistance in other work in progress.

Prof. F. E. Lloyd, of the Alabama Polytechnic Institute, was in residence at the Desert Laboratory in August 1910, during which time he reinvestigated certain features of stomatal movement and associated phenomena in *Verbena,* and extended his observations to *Amaranthus.* The results earlier published on *Verbena* (Publication No. 82) were confirmed. Stomatal movement and relative transpiration, water content (*a*) of the plant as a whole and (*b*) of the leaves, and absolute transpiration in the Ocotillo (*Fouquieria splendens*) were studied. Important correlations between fluctuation in transpiration rate and in water content were observed, bringing to light the necessity of further investigation of the relation between the income and outgo of water in the plants.

EQUIPMENT.

A number of pieces of apparatus of conventional types have been added to the equipment at Tucson and Carmel. A small plot of ground adjacent to the laboratory at Carmel has been purchased for experiments with cacti, while the cultures of species from high mountain habitats are installed in a leased garden tract.

The field-work in connection with Dr. Huntington's investigations upon desert climatic conditions involving some extended travel, a 30 horse-power motor with detachable tonneau was purchased and equipped with 34 x 4½

tires for use in sandy regions. Other special equipment was provided for field-work. Parties of two, three, or four persons were thus conveyed on trips across regions difficult of access by teams. The Mohave Desert and the Salton Basin in California were crossed, and work was accomplished in central, western, and southern Arizona, as well as northern Sonora. An average speed of 10 to 20 miles per hour may be maintained on even rough desert routes, and parties thus may go quickly from point to point. In the eight months ending September 1, the total distance accomplished was 6,000 miles.

THE STAFF.

Dr. H. A. Spoehr, of the University of Chicago, has been appointed a member of the staff, taking up his duties in connection with the position on September 1. He will devote attention to a group of problems in chemical physiology.

Dr. W. A. Cannon started in April for an extended trip to Algeria and Egypt for the purpose of extending his studies of desert plants, and has already obtained results bearing upon several problems under investigation by the Department.

DEPARTMENT OF ECONOMICS AND SOCIOLOGY.*

HENRY W. FARNAM, CHAIRMAN.

The work has proceeded throughout the year on the lines followed in the past. The negotiations with Prof. John R. Commons were brought to a conclusion in April 1910, and he has now assumed formal charge of the Division of Labor, which was originally under Colonel Wright. Under this agreement Professor Commons is to have the use of $4,000 appropriated from the general administration fund in addition to the balance of a little over $3,000 left to the credit of the Division of Labor by Colonel Wright. Professor Commons is at liberty to use for our purposes the material collected by him under the auspices of the Bureau of Industrial Research; also material collected under the auspices of the Carnegie Institution of Washington in a subsequent and different presentation of the subject to be made for the final volume or volumes of the Bureau of Industrial Research. The details may be found in a memorandum on file in the office of the Carnegie Institution of Washington.

The progress of the several divisions is reported by their heads as follows:

DIVISION I.—POPULATION AND IMMIGRATION.

Prof. Walter F. Willcox reports that the following works in his Division have been published since last year:

Chinese immigration. By Mary Roberts Coolidge. Henry Holt & Co., New York, pp. 531. 1909.

The German element in the United States. By Albert B. Faust. Houghton, Mifflin & Co., 2 vols., pp. 591 and 605, 1909. [A German translation is in preparation.]

The following have been completed but not published:

The economic status of the Syrians in the United States. By Louise S. Houghton.

The French contribution to the economic development of the United States. By Louise S. Houghton.

Professor Willcox hopes eventually to obtain a leave of absence from Cornell University in order to devote his entire time to finishing the work of his Division.

DIVISION II.—AGRICULTURE AND FORESTRY.

President Kenyon L. Butterfield reports that he has received a monograph entitled "The economic characteristics of the agricultural industry," by Prof. T. N. Carver, of Harvard University.

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*Address, Yale University, New Haven, Connecticut. (For previous reports see Year Books Nos. 3–8, inclusive.)

Regarding the unfinished part of his work, he reports that Prof. B. H. Hibbard is at work on the "Federal land policy" and hopes that this will be his last annual report of progress.

Prof. F. W. Blackmar has completed his study of "The social and economic phases of irrigation." He hopes to complete his general study of American agriculture down to 1840 within twelve to eighteen months.

Dr. E. D. Jones reports progress on his study of the "Development of the agricultural market since 1840."

Prof. H. C. Taylor has been somewhat delayed in his study of the "Development of the leading forms of land tenure" because both he and Dr. John L. Coulter have been called upon to give a great deal of time to the United States Census of Agriculture. Mr. L. C. Gray is devoting his time to the work of the Institution.

Division III.—MINING.

Mr. E. W. Parker reports that the following has been completed and published within the year:

History of the mining of gold and silver. By Walter R. Crane. John Wiley & Sons, New York, 1909.

The following studies have been received but not published:

A chapter on platinum. By Dr. David T. Day.
Chapters on aluminum, lithographic stone, fluorspar, and graphite. By Prof. Ira A. Williams.

The status of the unfinished work is as follows:

Prof. C. K. Leith has been delayed in his study of iron ore on account of his work in the Hudson Bay region and later by a month in Cuba. He hopes, however, that his report will soon be substantially ready for transmittal.

Mr. L. C. Graton has completed about 200 pages of the monograph on the history of the copper industry. He has been delayed because of the pressure of other work, but expects soon to be able to devote all of his time to the historical chapters.

Dr. F. B. Laney has been delayed by serious illness, extending from October 1909 to May 1910. He thinks, however, that he will be able to finish his study of the quarrying industry by spring.

No report has been received from Prof. Joseph Hyde Pratt on precious stones, abrasive materials, etc.; and Prof. Charles E. Munroe has been interrupted by the conditions prevailing in George Washington University.

Dr. David T. Day, whose chapter on platinum is mentioned above, expects to complete soon the chapters on quicksilver, antimony, etc. *

Mr. William E. Colby has recently been appointed lecturer on mining law at the University of California, and this is of material assistance to him in the preparation of his chapter.

Mr. Parker, in addition to the editorial condensation of the chapters already received, has been devoting himself to the preparation of the general chronology of mining.

*This chapter was completed in November 1910.

DIVISION IV.—MANUFACTURES.

Dr. Victor S. Clark has been in the Hawaiian Islands during the greater part of the year, where he has had charge of the United States census and of other government work. A study of the prices of raw materials and of manufactured commodities during the nineteenth century, which is being undertaken by Dr. Francis Walker, of the Bureau of Corporations, U. S. Department of Commerce and Labor, is partly finished. Dr. Clark has not yet completed his work in the Hawaiian Islands, but expects to have some time during the coming year to devote to his Division, and has accordingly had his papers and books shipped to Honolulu in order that he may be able to work upon them there.

DIVISION V.—TRANSPORTATION.

Prof. B. H. Meyer reports the publication within the year of the following:

Congressional history of railroads. By Lewis H. Haney. Vol. 2, 1850 to 1897, Madison, 1910, pp. 335.

The following study is finished but not published:

Transportation in the Pacific Northwest. By Prof. F. G. Young. Part I.

The following monographs are still unfinished:

The Granger movement. By Solon J. Buck.
Financial history of railroads, vol. 2. By F. A. Cleveland.
Canadian railways in their relation to railways in the United States. By S. J. MacLean.
Transportation in the Western cotton belt. By Prof. U. B. Phillips.
History of transportation on the Great Lakes. By George G. Tunnell.
The development of transportation in California and the growth of the transcontinental business. By Allyn A. Young.
Development of transportation in the Pacific Northwest. By Frederick G. Young.

Professor Meyer is at work upon the first part of the final report and hopes that the first volume of it will be ready in a year.

DIVISION VI.—DOMESTIC AND FOREIGN COMMERCE.

Prof. Emory R. Johnson reports the publication of the following monographs:

American commercial legislation before 1789. By Albert A. Giesecke. Publications of the University of Pennsylvania, pp. 175. 1910.
History of New England fisheries. By Raymond McFarland. Publications of the University of Pennsylvania. September 1910. About 400 pages.

The following has been completed but not published:

History of the foreign trade of the United States. By Drs. S. S. and G. G. Huebner.

The history of the American coastwise commerce, by Dr. Thomas Conway, jr., is nearly completed.

Professor Johnson has been finishing some work that he was already committed to, but expects to devote all of his available time now to completing the work of his Division and hopes to have the first half of it in final form by the end of 1911.

Division VII.—MONEY AND BANKING.

Prof. Davis R. Dewey reports the publication since last year of:

The early development of the national banking system. By W. W. Swanson, University of Chicago. Pp. 117.
The national banking system, 1863–1879. By G. D. Hancock.

Professor Dewey has written for publication by the National Monetary Commission:

The history of the second United States Bank.
State banking practice before the civil war.

He has finished a good deal of the preparatory work on his final report down to the civil war and has made some advance in the subsequent period.

Division VIII.—LABOR MOVEMENT.

As stated above, Prof. John R. Commons has now assumed formal direction of this Division. During the past year the following study, which was completed under Colonel Wright's direction, has been published:

Women in industry. By Edith Abbott. D. Appleton & Co., pp. 408, 1910.

The following has been completed, though not yet handed in:

The labor history of the Pacific Coast. By Ira B. Cross.

Professor Commons is at present engaged in issuing the "Documentary history of American industrial society," for which an appropriation was made by Colonel Wright. Nine volumes of this valuable collection of documents have now been published, and it is expected that the remaining two will appear before the close of the year. As soon as this documentary history has been finished, Professor Commons will devote himself to the preparation of his report, which he hopes to be able to complete in three years.

Division IX.—INDUSTRIAL ORGANIZATION.

Prof. J. W. Jenks has suspended work on his volume until some of the other divisions have finished theirs, in order to avoid duplication in collecting material. He has gathered as much as he thinks advisable for the present.

Division X.—SOCIAL LEGISLATION.

Since the last annual report, the following monographs have been published:

The labor legislation of Iowa. By Prof. E. H. Downey, State Historical Society of Iowa, pp. 283. 1910.
A history of California labor legislation, with an introductory sketch of the San Francisco labor movement. By Lucile Eaves. University of California Publications in Economics, vol. 2, pp. 461. August 23, 1910.
The child labor policy of New Jersey. By Arthur Sargent Field, Ph. D. American Economic Association Quarterly, third series, vol. XI, No. 3, pp. 229. October 1910.

The following monograph has been handed in:

Mechanics' lien laws of the United States. By Prof. W. L. Bailey.

Mr. McKitrick is making progress with his study of the land legislation of Texas, as is Dr. John L. Coulter with his monograph on the educational land grants of Wisconsin and South Dakota.

Mr. D. L. Peacock was obliged to suspend work during the winter on his study of the "Labor and rural credit policy of the Southern States," but has resumed work during the summer and has presented a chapter on "Agricultural credit in the South before the civil war."

Professor Farnam has arranged to be relieved from a large part of his academic duties during the coming year, in order to be able to devote himself to writing the report of his Division.

Division XI.—FEDERAL AND STATE FINANCE INCLUDING TAXATION.

Prof. Henry B. Gardner reports that nothing has been published in his Division during the past year. The progress of the work has been as follows:

Comparative study of the financial development of certain of the larger cities: Mr. Oliver C. Lockhart hopes to complete the work this summer.

Financial history of New Jersey: Mr. Edgar Dawson has completed a substantial portion of his work, but has been delayed by the pressure of other duties.

Financial history of Ohio: Prof. E. L. Bogart expects to finish the work soon.

Financial history of Texas: Mr. E. T. Miller expects to complete his study during the present year.

Financial history of Alabama: Mr. W. O. Scroggs expects to complete the work soon.

Financial history of Tennessee: Prof. St. George Sioussat expects to have his work substantially completed this year.

Financial history of Illinois: Prof. N. A. Weston has been unable to continue with the work, and it has been turned over to Mr. R. M. Haig, a graduate student of the University of Illinois.

Financial history of Minnesota: Dr. R. V. Phelan will probably complete this work during the present year.

Financial history of Oregon: Prof. F. G. Young has finished a portion of the work and it has been published in the Quarterly of the Oregon Historical Society, vol. VIII, No. 2, and vol. XII, No. 4, 1908. He expects to complete the work this year.

The financial history of California has been delayed by the absence in Europe of Prof. C. C. Plehn.

The financial history of Connecticut has been undertaken by Mr. Henry F. Walradt, a graduate student at Yale, who expects to complete it by June 1911.

Financial history of Indiana: Prof. W. A. Rawles has been prevented from making much progress with his work.

Financial history of Iowa: No report has been received from Prof. Frank I. Herriott.

License taxes of the Southern States: Prof. H. A. Millis has been obliged to temporarily abandon this work and has returned the funds advanced.

Financial history of South Carolina: Mr. George McCutchen has made no report.

Financial history of Virginia: Mr. Edgar Sydenstricker has made no report.

Financial history of Vermont: Mr. Frederick A. Wood has made no recent report, but the main portion of his work has been handed in.

New assignments have been made as follows:

The financial history of North Carolina, to Prof. W. K. Boyd, of Trinity College, Durham, N. C.

The financial history of New York, to Mr. Don C. Sowers, a graduate student at Columbia University.

The financial history of Pennsylvania was assigned to Prof. William Roy Smith, of Bryn Mawr College, but he has been compelled to abandon the work because of ill health.

Professor Gardner hopes to get his preparatory material in by next June and to apply for a leave of absence during the academic year 1911 to 1912 in order to devote himself to this work.

Division XII.—THE NEGRO IN SLAVERY AND FREEDOM.

Mr. Alfred H. Stone is still detained in Mississippi by his contest with the boll weevil. He has had the misfortune to lose two boxes of papers, books, and notes which were shipped from Washington. The railway company, after prosecuting the search for more than a year, has given up further effort. Mr. Stone will have the sympathy of his colleagues in this serious loss, which goes beyond the pecuniary value of books and notes and includes three chapters of his work practically completed and the skeletons of several others. Fortunately he has not lost courage, but is prosecuting the work with such material as he can use on his plantation.

He reports as follows regarding the work done by his assistants:

The following works have been completed but not published:

The free negro in Maryland. By J. M. Wright, Ph. D.
The free negro in Virginia. By C. H. Ambler, Ph. D.
The free negro in Louisiana. By Prof. E. P. Puckett.
The free negro in Philadelphia. By R. R. Wright, Ph. D.

The following monographs are still unfinished:

The economic transition from slavery to the free labor system. By W. L. Fleming, Ph. D.
The free negro in South Carolina. By Prof. Yates Snowden.

INDEX OF STATE DOCUMENTS.

Kentucky and Delaware have been added to the list of States for which the index has been completed by Miss Hasse. These were published by the Carnegie Institution of Washington in 1910, and contain 452 and 137 pages respectively.

The following is a complete list of States published, with year of publication:

California	1908	Massachusetts	1908
Delaware	1910	New Hampshire	1907
Illinois	1909	New York	1907
Kentucky	1910	Rhode Island	1908
Maine	1907	Vermont	1907

It will be seen that substantial progress has been made during the past year in almost all of the Divisions, and every effort will be made to bring the work to a conclusion at as early a date as possible.

SUMMARY.

It will be observed that the work of the Department thus far undertaken is of two distinct types: (1) Bibliographical; (2) Scholarly or Scientific.

The Index to State Documents falls in the first class and is analogous to the work which is being prosecuted by the Department of Historical Research. It is avowedly an aid to future workers. Most of our work falls in the second class and is analogous to the detailed studies made in the laboratories and observatories of the other departments of the Institution. Each study covers a limited field intensively.

The Department of Economics and Sociology differs, however, from the other departments of the Institution in two respects: In the first place it has undertaken a specific piece of work, namely, a systematic, orderly, scholarly series of Contributions to the Economic History of the United States. Thus, while its monographic work is extensive and, for the most part, valuable, it is treated by the department as preparatory to the larger undertaking. The greater part of it is unpublished, not because it lacks merit, but because of the difficulty of securing the publication of studies of this kind, which, however great their value to scholars, can not be expected to meet with large sales.

The second distinction between this department and the others is that it has relied to a large extent upon volunteer or only partly paid workers. This feature of its organization is to a certain extent necessitated by the kind of task which it has undertaken. A work projected upon so large a scale could not possibly have been carried out on the ordinary economic principle of paying the market price for work done, except at a very high cost. The insignificance of the sums spent in proportion to the results is obvious to any one who will take the trouble to make a simple calculation. Apart from the Index and the Administration expenses, the total amount spent on re-

search and scientific work during more than five years was less than $94,000. As there are 12 divisions, it is clear that this is an average for each division of less than $8,000 in five years, or less than $1,600 a year.

If we should count as our output only the more extended monographs and books, entirely disregarding the large amount of partly finished work done by the collaborators and others, we should have about 134 extended studies. Therefore, if we had done nothing else, and had spent our $94,000 on these things alone, they would average about $700 apiece.

When, upon the creation of the Carnegie Institution of Washington, a number of economists were consulted regarding the first undertaking to be assigned to a Department of Economics and Sociology, they agreed unanimously, and each independently of the others, that the most important work to undertake was a study of the methods and the influences under which our wonderful economic development had taken place, before the evidence, both documentary and human, should have been lost. This same idea was suggested at an earlier date by General Francis A. Walker, a short time before his death.

In order to carry out such a great plan, all recognized that cooperation was necessary. The general interest taken in the plan is shown by the fact that the American Economic Association and the American Historical Association formally invited Colonel Wright to deliver an address upon the subject at the annual meeting held in December 1904. The address was followed by a discussion, which showed a general interest in, and approval of, the project. I believe that the work when completed will be a credit to American scholarship. But work of this kind takes time as well as money; and in view of the amount already accomplished it would, in my judgment, be a mistake of the first magnitude to either curtail the work itself or lower its standard by insisting upon a too rapid completion.

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. Davenport, Director.

GENERAL STATEMENT OF RESULTS.

The progress in the year ending October 1, 1910, made by this Department in the subject under its charge may be considered under seven heads: origin of characteristics, their chemical basis, ontogenesis, transmission, modification by environment, relations, and the application of heredity to man.

THE ORIGIN OF CHARACTERISTICS.

While the breeder can as yet rarely induce at will a wholly new characteristic by experimental methods, yet in breeding large numbers of individuals new characteristics are occasionally found the proper breeding of which may result in a distinct strain. Thus, among the 17,000 pedigreed poultry bred by us such characteristics have appeared—at first hardly noticeable, but in the past few years becoming well marked and even striking. Among such are toes without nails; toes with double nails; extra tubercles on the side of the single comb which have given rise to a row of such tubercles in later generations; large depressions on the ridge of the beak (associated with an imperfect development of the nasal bone); and a horn on the ridge of the beak. Among plants, likewise, such characteristics have occurred, if not absolutely unparalleled, at least new to the species under consideration; such as æcidia or cup-shaped foldings of leaves, "quilling" of the lappets of compositæ, triple cotyledons, fasciations. We are not yet able to induce these at will in any strain, but have developed strains in which some of these conditions are normal.

The origin of spots on the wing-covers of lady-beetles has been particularly considered by Mr. Johnson, in his publication on that group, and he concludes that the evolution of any changes inside of species is chiefly the loss or the confluence of spots. The differences are often of a qualitative order.

THE CHEMICAL BASIS OF CHARACTERISTICS.

Substantial advance has been made in this subject during the current year in consequence of the appointment of Dr. Gortner and the equipment of a chemical laboratory. In the first place, fundamental defects in current methods of isolating the black pigment of hair, wool, and feathers were discovered. With the improved method the assertion that dominant white has a hyperoxidized black pigment was shown to be incorrect. In neither dominant nor recessive white is pigment formed; the additional factor in the dominant type is suspected to be an anti-enzyme.

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* Situated at Cold Spring Harbor, Long Island, N. Y. Grant No. 601. $30,970 for investigations and maintenance during 1910. (For previous reports see Year Books Nos. 3–8.)

THE ONTOGENESIS OF CHARACTERISTICS.

In the studies on the comb, tail, and feet of fowl conclusions were reached concerning dominance based on the relative frequency of occurrence of the dominant characteristic and its opposite in the second hybrid and subsequent generations. To test the hypothesis that dominance is due to the *presence* of something, while recessiveness is due to its *absence,* it was desirable to have studies made on the embryological development of the characteristics. For instance, there are "rumpless" fowl and the behavior of rumplessness in breeding suggests the hypothesis that this defect is due to a something that stops the normal development of the tail. Does the development of the tail region in the rumpless fowl give evidence on this point? Miss Elizabeth S. Lum has started an investigation of this point and some time will be required to complete it. It is significant that the rumpless fowl at first has a pointed tail, but its development seems to be prematurely interrupted as though there were present a local inhibitor of development.

Similarly the evidence from heredity indicated that the webbing (syndactylism) in the foot of some poultry is due to the presence of a factor absent in birds with non-webbed feet. The study of the developmental history of this characteristic has been begun by Mr. E. Carleton MacDowell, and is calculated to throw light on the process by which distinct digits are formed from the primitive paddle-like tip of the appendage. The extended studies that we have made on the inheritance of the varied forms of the comb of fowl raised so many questions concerning the factors involved in the development of the comb that we were glad to supply Mr. J. C. Stephenson, of the University of Chicago, with a variety of types of comb for the study of the embryology of this organ, upon which a report is soon to be expected.

THE TRANSMISSION OF CHARACTERISTICS.

This subject, heredity, has received more attention from us than any other, and the longer it is studied the more the subject develops. The two most voluminous publications of the year, that of Mr. Roswell Hill Johnson and my own, deal with this topic, and some account of their scope and general conclusions may be given. Mr. Johnson's paper is entitled "Determinate evolution in the color-pattern of the lady-beetles." These beetles are quite undomesticated and much labor was necessary to make them breed abundantly in captivity, the more so as most of them require living insects as food; nevertheless Mr. Johnson was very successful. He concludes that segregation of characters occurs in the hybridization of these beetles, but is not always clean-cut, and that dominance is irregular and variable in degree. He introduces the term "preponderance" to denote the fact of frequent excess in numbers of extracted "dominants."

Dr. F. E. Lutz, whose paper on heredity of characteristics in the fruit-fly has been submitted for publication, likewise finds "dominance" very irregular, and Dr. Shull has shown how in many cases it may be difficult or impossible to detect.

The "Inheritance of characteristics in domestic fowl" is a continuation of "Inheritance in poultry." The principal results are a demonstration of variation in the degree of dominance (illustrated by the relative proportion of the two elements in the hybrid between single and V comb) and of the inheritance of such degree. This variation in dominance shows itself also in polydactylism, syndactylism, and rumplessness. A study is also made of some characters that seem to blend, such as foot-feathering and nostril-height, and it is shown that even in these cases there is evidence of segregation, so that the probability is strengthened that segregation is never absent in inheritance and Galton's three types of heredity are merely different forms of segregated heredity. A case of apparent failure to transmit a character (comb-lop) is found. This adds another to the two or three previously known cases of non-inheritance of a right and left character. The complex factors of the plumage colors of several varieties of poultry were disentangled and simple formulæ discovered by which the proportions of any color in a given hybrid mating can be predicted.

Progress has been made in the analysis of the method of inheritance of sex by breeding over 200 families of a species of *Lychnis,* which affords male, female, and hermaphrodite individuals. To this problem Dr. Shull is devoting a large part of his attention.

The studies on inheritance of human characteristics have been greatly developed, and a booklet on "Eugenics," written by the Director, has awakened interest in the improvement of mankind by better breeding and has led to the establishment during the year of a eugenics record office at Cold Spring Harbor, in connection with the American Breeders' Association and supported from an outside source.

The studies on the relation of chromosomes to heredity, carried on by Miss Lutz, are yielding results of increasing interest.

THE MODIFICATION OF CHARACTERISTICS.

The results of Mr. R. H. Johnson's experiments in subjecting larvæ of lady-beetles to variations in temperature have been published. By subjecting larvæ to a low temperature new lines and spots of pigment appeared on the elytra. The study of the inheritableness of this changed pattern was not completed.

The relation of general vegetative vigor and variability to pure-line breeding in corn and to hybridization between pure lines has been further investigated by Dr. Shull and his earlier results sustained.

The Department is cooperating with Prof. H. H. Donaldson, of the Wistar Institute of Anatomy and Biology, in an experiment on albino rats. As Professor Donaldson has shown, albino rats have a nervous system that is much smaller in proportion to the weight of the entire body than that of Norway rats, and it seems probable that this is due to the fact that they have always been reared in cages. It was desired to set them at liberty in a place whence they could not escape. Accordingly it was decided to employ Goose

Island for this experiment, as it seemed to offer ideal conditions and as brown rats were known to inhabit it. An attempt was made to kill off the brown rats, and several pairs of white rats were then set free June 21, 1910.

The conclusions of Dr. C. C. Guthrie, that germ-cells of one race of poultry introduced into another race produced offspring with some of the characters of the foster-mother, was thoroughly tested by me, using pedigreed stock, and overthrown. There is at present no evidence that, in poultry, transplanted germ cells survive, much less that the "foster mother" modifies the inherent inheritable characters of the germ plasm.

On the other hand, the germ cells do receive nutritive materials from the maternal body and the details and limitations of this process are of great importance. Dr. Oscar Riddle, of the University of Chicago, spent some time at this Station during the year investigating this topic. Particularly he studied the permeability of the envelopes of the animal germ cell (fowl) to foreign bodies—especially to natural and artificial coloring matters. Positive results were obtained with nine such substances, and negative results with about forty others. He also studied the oxidizing and reducing properties of germinal elements and their surrounding tissues as these can be measured in the fowl by means of reducible and reoxidizable color-compounds. The investigation of both these subjects is still incomplete.

THE RELATIONS OF CHARACTERISTICS.

By means of extensive statistical studies Dr. Harris has determined that in *Staphylea* there is a real selective elimination of the fruit with fewer and more variable ovules and of those that are asymmetrical or have an odd number of ovules to a compartment of the ovary. To studies in elimination which stop at mere statement of the statistical fact there will always be the unsatisfied inquiry as to the mechanism of this elimination.

A case (land snails of the Bahama Islands) that has lately been cited as evidence against mutation was examined by me at New Providence and facts found that support the interpretation of their mutational origin or at least do not warrant the conclusion that the various forms can have arisen only by "selection."

STAFF.

Dr. G. H. Shull spent a larger part of the year than usual (all except January to April) on the Burbank work at Santa Rosa, and he will continue there until next spring. The necessary but difficult work of supervising the planting and hand-pollinating of Dr. Shull's cultures was done in a satisfactory manner by Mr. R. C. Rose, now of the New Hampshire Experiment Station, who was resident from June 1 to September 10. Dr. J. A. Harris spent some months in England and Germany during the winter, carrying on his computations and writing up results there. Dr. Banta visited Mayfield's Cave, Indiana, during a part of May in order to get cave animals for his studies at Cold Spring Harbor.

DETAILED REPORTS ON SCIENTIFIC WORK.

WORK ON HEREDITY IN ANIMALS.

Poultry.—In continuation of the experiments with poultry, 53 pens were maintained and over 3,500 chicks hatched. Fireless brooders were used exclusively for the outdoor brooding with entire satisfaction. Progress was made in developing rumpless, nailless, syndactyl, polydactyl, and combless strains; also new forms of comb, nostril, and boot. Several sets of experiments on potency and reciprocals were undertaken, and the results of grafting and abnormal temperatures studied.

Finches.—The breeding of canary birds was continued but, owing to the use of many young birds this year, the fecundity was small, only about 30 being reared. Interesting results were gained from the second hybrid generation of Java sparrows, since nearly pure white (with a little smokiness) were obtained from the gray hybrids of the first generation.

Sheep and Goats.—Fourteen sheep and six goats were born. The lop ear of the Indian goat is dominant over erect ear of the Irish goat as truly as accessory auricles are dominant over their absence. The black ram with 6 nipples, from Mr. Alexander Graham Bell's flock, is being replaced by a 4-horned, 3-nippled sheep, also a gift to the station from Mr. Bell.

Cats.—The new cat-house has proved well adapted to its purposes and the health and fertility of the stock are much improved.

WORK ON PLANTS.

The continuation of Dr. Shull's experiments was confided to the care of Mr. R. Catlin Rose, for whose guidance Dr. Shull prepared full detailed instructions. In order to simplify this work as much as possible, a number of problems which have been under investigation in previous years were omitted for this year and the more important ones somewhat enlarged.

Sex and Flower Color in Lychnis.—The studies in the inheritance of sex and color-characters in *Lychnis* have been Dr. Shull's largest project of the year. The results of the work with *Lychnis* are confirmatory of those already published, and numerous crosses have been made to test certain new phases of the subject. The attempt to secure a pure-bred purple-flowered strain of *Lychnis* has again failed of attainment, owing to the fact that in each cross made for this purpose one or the other parent proved to be heterozygous. The effort is to be continued in order that material of definitely known hereditary characters may be available for use in subsequent experiments. As in previous generations, several new mutants of *Lychnis* having hermaphrodite flowers have appeared this year, but they constitute an exceedingly small percentage of the individuals grown. The crosses in which hermaphrodites were used as the male parents have again been found to result in progenies in which the male members are hermaphrodites. Normal male mutants also appear rarely in these families. True males may occa-

sionally possess female organs as a purely somatic character. There was indication last year that the egg-cells of hermaphrodites do not possess the capacity to regularly produce hermaphrodite offspring, as the sperm-cells of the same plants do. The crucial test of this matter is a cross of unusual difficulty, in which the hermaphrodite is used as the female parent, and but little success has yet been attained in securing crosses of this nature. However, the one family of this type tested this year again indicates that the hermaphrodite condition is not regularly inheritable through the egg, but only through the sperm. Dr. Shull hopes that a concentration upon this phase of the question may in future give sufficient material to clearly demonstrate the relation between the sexes in *Lychnis*.

Indian Corn.—These cultures were also enlarged by Dr. Shull in order to thoroughly test the relation between self-fertilized and cross-fertilized offspring within the same families, not only in pure-bred, continuously self-fertilized lines, but also in first-generation and second-generation hybrid families. Special attention has been given also to the relative vigor and variability of second-generation hybrids as compared with first-generation hybrids and with pure lines. The result of last year's crop indicated that the first-generation hybrids between pure lines present the same degree of fluctuation as the pure lines themselves, while the second generation is considerably more variable. The second generation was also considerably less vigorous on the average than the first generation. Both of these results were in perfect accord with conclusions previously gained and already published. As the corn is not harvested at the time this report is made, the outcome of the further tests of these points can not be summarized here.

Oenothera Breeding.—The continuation of Dr. Shull's cultures of cross-fertilized and self-fertilized families in *Oenothera lamarckiana* and *O. rubrinervis* has been made possible through the kindness of Miss Lutz, who has carefully kept all notes and made the necessary crosses. A considerable number of new forms have been detected whose status as mutants it is hoped to test by subsequent breeding.

The number and size of cultures involved in Dr. Shull's investigations may be noted in the following table:

Name of species.	No. of families.	No. of individuals.	Name of species.	No. of families.	No. of individuals.
Chrysanthemum maximum	1	105	Lychnis(melaudrium) rubrum	5	277
Chrysanthemum nipponi	1	125	Oenothera	23	3,437
Digitalis	11	2,530	Rudbeckia hirta	1	100
Lychnis dioica	216	14,099	Zea mays	76	6,409
Lychnis haageana	3	110	Total	337	27,192

Variation in Wild Plants.—Pressure of experimental work has made it necessary for Dr. Harris to limit his work along these lines almost exclusively to fertility characters.

Quantitative Investigations of Fertility and Fecundity in Plants.—These studies have been carried forward by Dr. Harris, as time permitted, along the lines indicated in Year Book No. 8. Some of the data have been published and others are in press, while a very large mass of material awaits the final processes of reduction.

Investigations of Variation, Correlation, and Inheritance of Quantitative Characters in Garden Beans.—As stated in Year Book No. 8, where an indication of the chief problems may be found, Dr. Harris's attention since coming to the station has been chiefly devoted to these investigations. The cultures of the present season, involving the planting of about 20,000 seeds, were devoted to a comparison under like conditions of the offspring of ancestors grown for two generations under very dissimilar environmental conditions. Owing to the large amount of routine counting, weighing, tabulation, and calculation the results from these experiments can not be ready for a considerable length of time.

Studies in Vegetable Teratology.—The results of about 125,000 dissections of normal and proliferous fruits of *Passiflora*, grown in 1908 and 1909, are being studied statistically by Dr. Harris to determine various points concerning the nature of teratological variation and the frequency of the several types of anomaly to which a fruit may be subject. Until this routine can be carried through, further cultures of *Passiflora* have been suspended. Breeding experiments with teratological beans have been continued. Approximately 50,000 seedlings have been studied.

Quantitative Studies of Selective Elimination.—Natural selection is one of the factors of organic evolution least investigated by the quantitative biologist. Dr. Harris has attempted to gain some light on the structural characters which are least fitted for development by studying the characters of ovaries which fail to develop to maturity as compared with those which develop. The analysis of data for *Staphylea*, collected in the spring of 1906 and 1908, justifies the following conclusions:

The failure of ovaries to develop to maturity is not random, but is dependent upon structural peculiarities which would admirably be classed as "fluctuating variations." In short, the elimination is selective, whether we work within the range of variation of the ovaries of an individual or extend the studies to ovaries from a number of individuals. The changes brought about by selective elimination are:

1. An increase in the mean number of ovules.
2. A decrease in variability of number of ovules.
3. A decrease in radial asymmetry as measured by the standard deviation of number of ovules per locule for an individual ovary.
4. A decrease in the relative numbers of ovaries with one or more locules with an odd number of ovules.
5. Possibly an increase in the mean number of locules per fruit.

Preparations were made for carrying this work forward in 1910, but a severe freeze killed all the material.

CELL STUDIES IN HEREDITY.

Miss Lutz continued the study of the somatic chromosomes of the oenotheras and their hybrids begun four years ago and carried on ever since with great industry, over 4,300 fixations having been prepared for microscopical study; in the best-studied hybrids photographs have been made of type and exceptional forms to illustrate distinctive characters of early and late rosette stages, young and adult flowering plant, bud, flower, leaf, and fruit; in all about 350 plates.

Of the 14 or more topics upon which some data have been obtained the 5 following are nearing completion and will, it is hoped, be finished during the coming winter:

1. Chromosomal history of the F_1 offspring of *Oenothera lata* × *O. gigas*.
2. The F_2 offspring of *Oenothera lata* × *O. gigas*.
3. The chromosomes of mutants.
4. Pollen of the oenotheras and its relation to mutation.
5. Sex chromosomes of *Lychnis*.

STUDIES ON ADJUSTMENT TO CAVE LIFE.

During the winter a concrete cave was built, as described in detail under "construction," and a dark-room was fitted up with apparatus for the study of the reactions of organisms to light. The purpose of the cave studies is to learn the way in which body pigment is lost, eyes degenerate or disappear, and tactile organs hypertrophy in animals inhabiting caves, abysmal waters, and other dark situations.

Dr. A. M. Banta assumed charge of this work about November 1, 1909, and since that time has been busy collecting cave animals and installing and maintaining them in daylight as well as in darkness. Closely related species that ordinarily live in the light are being reared in the dark. A necessary, though laborious, part of the work has been acquiring the technique of maintaining the animals. Each species presents a problem in itself, and many of these problems have been solved. The artificial cave affords conditions approximating those of a natural cavern, with the advantages of constant accessibility and of convenience for caring for the organisms.

The following are now breeding within the cave:

Asellus communis.
Eucrangonyx gracilis (surface form).
Oniscus asellus.
Armadillidium vulgare.
Porcellio scaber.
Porcellio rathkei.
Copepoda.
Drosophila.
Tenebrio.
Silvanus.

The following animals are being kept in the cave for the purpose of breeding:

Guinea-pigs.
Goldfish.
Sunfish (Lepomis gibbosus).
Crayfish (Cambarus bartoni).
Myriapoda.
Thysanura.
Ceuthophilus.

In addition, larvæ of 4 species of amphibians are being reared in the cave.

The following cave forms are being kept in daylight:

Cambarus pelucidus.
Cæcidotea stygia.
Eucrangonyx gracilis.
Sinella cavernarum.
Rhagidia cavicola.

Some time has been devoted by Dr. Banta to a comparative study of the light reactions of the cave form of the amphipod *Eucrangonyx gracilis* and the form of the same species found in surface streams in the same localities. The work on the normal light reactions of these forms should be completed soon. Two parts of a similar study, "A comparison of the reactions of a species of surface isopod with those of a subterranean species," previously completed, have been published during the year in the Journal of Experimental Zoology. With the species used, *Asellus communis* and its near relative of cave habitat, *Cœcidotea stygia*, there was found a great difference in reactiveness to light and to mechanical stimulation. The cave form was responsive (negatively) only to rather high intensities of light, while it was exceedingly responsive to all sorts of mechanical stimulation. On the other hand, *Asellus* was responsive (also negatively) to comparatively low light intensities, though it fell far behind *Cœcidotea* in its responsiveness to tactile stimulation. With *Cœcidotea* there was increased sensitiveness to one sort of stimulation to compensate for partial loss of responsiveness to another sort. Having a bearing on the respective habitats of the two species was the fact that *Asellus* is *positive* in its response to light after retention in darkness for a time, while *Cœcidotea* is always negative to any intensity to which it responds at all. Hence *Asellus*, if happening within a cave, would tend to leave it after a time if, by chance, it came within reach of the light from outside, while *Cœcidotea* is always negative in its response and responds to a sufficient range of intensities to prevent its leaving a cave and passing into daylight outside.

Studies have been made on sex recognition and the breeding-habits of *Asellus*. An unsuccessful attempt was made to breed from an albino strain of *Asellus*, but the experiment is being continued.

Observations are being made for possible modifications in light reactions as well as pigment changes in the various forms in their changed environments; and upon the effect of absence of light upon the development of certain amphibian larvæ.

CHEMISTRY OF PIGMENTS.

During the past year Dr. R. A. Gortner has been in charge of the chemical laboratory fitted up for his use, in the study of organic pigmentation. He reports as follows:

During the past year the investigations carried out in the chemical laboratory have been largely of a preliminary nature. In pursuance of an endeavor to ascertain the origin, mode of formation, and chemical nature of compounds of the melanin class it was found necessary to determine the form in which the pigment is present in the animal body, skin, hair, or feathers. The greater part of the time has, therefore, been utilized in isolating the pigment from black sheep's wool by destroying the keratin structure with alkali or acid of varying concentration, then purifying the melanin and subjecting it to a chemical analysis. By a comparison of the data from this series the effect of alkali or acid upon the melanin molecule could be determined.

It was found that alkali in excess of 0.2 per cent concentration (calculated as sodium hydrate) readily destroyed the greater portion of the pigment molecule and caused a great loss in both the nitrogen and hydrogen content. The yields of the melanin obtained by the different methods are given in table I and the analytical data is shown in table II.

In addition to this work the pigmentation of the meal-worm (*Tenebrio molitor*) was studied and was found to be due to the interaction of an oxidase and an oxidizable chromogen.

A study of dominant and recessive white was also undertaken and the conclusions arrived at were that the plumage or hair of both varieties do not differ, chemically, to any appreciable extent, *i. e.*, the dominant whites do not possess a pigment which is lacking in the recessive whites, but that an inhibitory enzyme is probably present in the dominant whites which, acting as the determiner, prevents pigment formation, while the recessive whites have neither the power to form melanin nor the ability to inhibit its formation.

TABLE I.—*Percentage yields of ash-free melanin obtained from black wool by extraction with increasing strengths of alkali.*

	Acid-soluble pigment.	Acid-insoluble pigment.		Acid-soluble pigment.	Acid-insoluble pigment.
NaOH, 0.2 per cent...	8.10	1.36	NaOH, 10 per cent...	.....	2.43
NaOH, 1 per cent.....	.....	3.26	NaOH, 20 per cent...	.....	1.78
NaOH, 2.5 per cent...	.....	2.95	NaOH, 30 per cent...	.....	1.71
NaOH, 5 per cent.....	.....	3.62	NaOH, 50 per cent...	.....	1.56
NaOH, 6 per cent.....	.....	1.95	H_2SO_4, 25 per cent...	.....	2.00

TABLE II.—*Analytical data obtained by a study of the pigments isolated by the different methods.*

Method.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen (by diff.).
	per cent.	*per cent.*	*per cent.*	*per cent.*	*per cent.*
0.2 per cent NaOH, acid soluble	52.60	7.28	13.52	1.33	25.25
0.2 per cent NaOH, acid insoluble	53.44	5.81	10.44	1.10	29.15
1 per cent NaOH	52.20	6.62	10.34	1.06	29.78
2.5 per cent NaOH	53.07	5.82	9 37	1.06	30.68
5 per cent NaOH	53 16	5.71	9.22	1.05	30.86
10 per cent NaOH	56.01	4.88	7.03	1.24	30.84
20 per cent NaOH	56.52	4.28	6.19	1.27	31.74
30 per cent NaOH	56.71	4.30	5 12	1.46	32.41
50 per cent NaOH	57.06	3.84	8.98	1.27	28.85
25 per cent H_2SO_4	57.81	4.40	5.50	1.75	30.52

HUMAN HEREDITY.

In connection with the eugenics section of the American Breeders' Association and its committees, the application of the new principles of heredity to man is making satisfactory progress. Mrs. Davenport and the Director have just completed a paper on "Skin-color in man," in which progress is made on the following points:

(*a*) It is shown that skin coloration of white races is not a blend, but segregates and follows the general law, first pointed out by us in the case of hair-color, that, in general, the skin-color of the children is not darker than

that of their darker parent. Consequently two blond parents have only blond offspring, but a blond and a brunet may have either blond or brunet children.

(*b*) It is shown that in crosses between negroes and Caucasians the same rule holds: that mulattoes produce "white" children, but (probably) rarely black, and that, consequently, the assumed blend of coloration is not a permanent thing.

(*c*) Intensive studies of about 30 albino families give every reason for concluding that albinism in man, in opposition to current opinion, is really inherited exactly as in rabbits and guinea-pigs. An explanation is given of the apparent departures from the rule for other mammals. New and relatively extensive evidence is given that the high consanguinity in the parentage of albinos that is to be expected actually occurs—that albinism is *prima facie* evidence of consanguineous marriages. From the evidence gained by the cooperation of the committees on feeble-mindedness, it appears that imbecility, insanity (of certain forms, at least), and epilepsy are inherited in like fashion, and that where both parents lack the factor for normal brain development all of their children will lack it also, and be defective.

The work on human heredity has grown to such proportions and its outlook is so vast that it became evident that the Director of this Department could not cope with it alone. Much assistance was needed. Fortunately, at an opportune moment, assistance was forthcoming. The Eugenics Record Office has been established in a place close by and placed under the control of your Director with funds for the maintenance of a superintendent, office assistants, and a number of field workers. The outlook for the development of this very practical offshoot of our work is bright.

EQUIPMENT AND CONSTRUCTION.

On January 11, 1910, the Institution purchased for the use of the Department 21 acres of land lying about a mile east of the station building. This is largely wooded. About 4 acres have been used during the present season for growing *Lychnis* in the sex experiment and for pedigreed beans. From about 4 acres in addition a hay crop was obtained. The land lies high and is otherwise favorably situated, but lacks means of irrigation which can be easily arranged for. The purchase provides for the natural expansion of the work of the Department for some time to come. It was made at an opportune time, in view of the rapid rise in the price of land, and gives great satisfaction to the Department.

During the winter an artificial cave was constructed, connected with the building at its northwest corner. The inside dimensions are 41 feet long, 8 feet wide, and 6.5 feet high. The top is 4 feet below the surface of the ground. The walls, roof, floor, partitions, and shelves are of concrete reinforced with one-fourth-inch steel rods. The cave is divided, by two partitions with iron doors, into three rooms, of which the first is separated from

the basement of the laboratory by a door of refrigerator construction. Each room contains two or three large tanks about 4 by 4 feet for fishes; two of the rooms contain a series of smaller tanks elevated 3 feet above the floor, for smaller aquatic animals, such as Crustacea. The bottom of each of the smaller tanks is sloping, affording a variable depth of water. Constantly running water from a flowing artesian well enters each compartment through ebonite cocks, and the overflow runs into the sand and gravel that forms the floor of the cave. No outlet pipe is possible, because the floor of the cave is below the level of high tide; the natural soil forms a dam to the influx of sea-water. After the concrete tanks were made it was found necessary to heat them and infiltrate with paraffine to prevent the formation of a limy acid that was fatal to the organisms. A shelf running above the tanks on one side affords room for jars containing terrestrial organisms. The cave is ventilated at each end and is provided with electric bulbs of ruby glass and also of clear glass. The cave opens into a dark basement room which has been provided with apparatus to test the light reaction of organisms.

In the early part of the fiscal year a chemical room was fitted up by partitioning off a portion of the north room on the first floor. All woodwork except the window trim was sheathed with asbestos board. A chemical table and hood were put in place. A gasolene gas-machine was installed, supplying not only the chemical room but also the six incubators, and is available for all the investigator's rooms.

Among other things a concrete wall 16 feet long was put up to hold back enough salt-water in the pond to make it possible to pump at any state of tide and to use in case of fire.

MAINTENANCE.

Pipes were reset in the greenhouse and the floor partly concreted; the wooden stable-floor was replaced by concrete, the hay-mow remodeled, sundry cases and trap-nests manufactured as required, and the lawns and paths maintained in fair order.

GEOPHYSICAL LABORATORY.*

ARTHUR L. DAY, DIRECTOR.

Although the earlier reports of this Department have contained brief statements of the purpose with which this work was undertaken, viz., to enter upon a *quantitative* study of rock formation in the laboratory, which shall include both the minerals and rocks which are geologically important and those which are economically useful, those which are formed directly from the magma and those which were formed by subsequent alteration, there are some details of such an undertaking which are quite as important as an explicit statement of purpose. The individual problems contemplated by such a plan are problems for physics and physical chemistry. Furthermore, a number of these problems are in no sense new. It is therefore a matter of at least equal interest to know why, if such problems have already been recognized and some of them even widely discussed, they have not been wholly or partly solved before. Are there questions of practicability in making such an application of the measuring sciences to the mineral kingdom which have operated to discourage such attempts in time past, and, if so, is the outlook more favorable now?

One of the most important reasons for this delay in attacking these obvious problems lies in the fact that the measured relations established by the exact sciences have not been of adequate scope to meet the needs of large geologic or petrologic questions. The great body of physical and physico-chemical measurements have been confined, for example, to the region between 0° and 100°, while rock formation may have extended over a temperature region reaching to 1500°, or perhaps even higher—an enormous range over which to stretch the application of methods and one in which the common forms of apparatus will not only fail, but the apparatus itself is immediately threatened with destruction.

It is, therefore, not altogether certain, at least not without additional physical and physico-chemical investigation, that the generalizations hitherto established are directly applicable to problems of geophysical scope. There has been a gradual recognition of the fact that although many of the problems of geology and of petrology are directly physical in character, they are separated by an unexplored region from most of the laboratory methods and measurements undertaken in our laboratories. To bridge this gulf the physicist has done but little, perhaps because of failure to appreciate the opportunity or need for it; and the petrologist has not been sufficiently familiar with the tools in use by the exact sciences.

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* Situated in Washington, D. C. Grant No. 602. $51,020 for investigations and maintenance during 1910. (For previous reports see Year Books Nos. 3–8.)

The earlier measurements of mineral melting-points contain an excellent illustration of this. But a few years ago a long list of minerals was melted and the melting temperatures measured with an apparatus which yielded results correct within perhaps 25°. Most of the important minerals were found to fall within the region between 1100° and 1300° C. The result obviously merely served to divide the minerals, somewhat roughly, into eight classes upon the basis of melting temperature, a classification so rough as to be of but little service to petrology. Over against this illustration, it may be noted that as soon as attention was properly directed to the situation, improvements were devised and made available for such measurements which now enable us to detect temperature differences smaller than 0.1° in the behavior of minerals in this region—a precision entirely comparable with the corresponding measurements of physics at ordinary temperatures.

The Geophysical Laboratory is making a direct effort to meet just this desideratum, and to make of petrology an exact science also. Throughout the history of this laboratory we have sought to begin with problems which permitted accurate quantitative definition, both of the materials and of the forces which participate in the reactions as they occur, and to use the successful solution of one such problem as a stone with which to build a broader foundation for the next. It is a working plan which consciously goes out after difficulties, but it is imperative that laboratory study undertaken in the service of the various branches of geology should become commensurate in scope with the geological problems which it seeks to solve.

To make an accurate estimate of the character of the work of the year just past, and of our plans for the future, it will be necessary to bear constantly in mind that the existing methods and generalizations of physics and physical chemistry are rarely adequate *in their present scope* to reach even the simpler problems offered by the rocks during formation. A considerable proportion of the activities of the Geophysical Laboratory, both in the present and in the immediate future, will therefore necessarily be directed by the need for greater scope in the physical and physico-chemical generalizations which can be applied to rock formation.

To be explicit, the efforts so far made are four in number:

(1) To extend the methods of accurate temperature measurement to include the entire field of rock formation. This work, covering the establishment of a fundamental temperature scale and several modes of applying it to the minerals, is now practically completed for the temperature range from 0 to 1550° C., where all known rocks are molten.

After devising means to determine the temperature at which minerals form, thus providing a temperature scale in terms of which the history of the cooling earth could be expressed, it became necessary (2) to measure the amount of energy involved in certain phases of the formation process. Here, again, the methods of physics (calorimetry) were complicated in technical character and seriously limited in scope and accuracy. Hardly an attempt had been made to determine the quantity of heat involved in chemical reac-

tions at temperatures as high as those at which minerals form, and even in the most accessible temperature region, that is, at the temperatures of everyday life, an error of 0.5 per cent was usually considered inevitable in such measurements. Six papers have been published from this laboratory during the present year which deal with the problems of calorimetric measurement alone. Of the result attained, it may be said that specific heats can now be measured in any portion of the temperature range stated above with an accuracy ten times greater than that usually found in similar measurements at ordinary temperatures. It remains to devise methods of applying this system to the determination of heats of formation as well.

(3) The third direction in which the available methods proved inadequate was in the microscopic examination, or more generally in the determination of the crystallographic and optical character of the crystals formed in our solutions. Early in our investigations it appeared that the attempt to produce in the laboratory crystal types of high chemical purity almost invariably resulted in crystals so small, when compared with those found in nature, that the usual methods of study were not equal to the task unless considerable sacrifices of accuracy were made. From our quantitative viewpoint, obviously, sacrifices of this kind were carrying us in the wrong direction. The question of methods and technique in the determination of crystals under the microscope was therefore taken up with similar thoroughness and is now practically completed. Submicroscopic crystals, of course, are no more accessible to study than heretofore; but crystals of but a few hundredths of a millimeter in their chief dimensions can now be determined with as great certainty as is ordinarily possible in large natural crystals. Not only this, but the precision attained in technical measurements of this kind has made necessary a fundamental study of the optical principles underlying the passage of light through inactive plates which sets definite limits to the attainable accuracy in a certain class of optical measurements and is a contribution of considerable value to the general subject of physical optics. The paper referred to is very briefly reviewed on page 95 and the entire collection of new optical methods will be published in book form during the coming year.

(4) The fourth task which the limitations of existing physical methods has imposed upon these studies is the total inadequacy of methods for the application and measurement of high pressures, especially when combined with the high temperatures necessary for many of the problems of rock formation. In this direction, however, we are not yet ready to offer more than a general report of progress on account of the very serious technical difficulties which have been encountered.

A fifth difficulty can also be foreseen in the limitations of physico-chemical theory and experience with which to attack polycomponent systems. Combinations of two minerals or of three find more or less helpful analogues in existing studies of salt solutions at low temperatures, but when four or more minerals are found together, as in the case of most of our rocks, their relation must be determined *ab initio*. The methods which have been thus far

employed by physical chemists in systems of four and five components will require to be completely remodeled for the study of complicated silicates.

From this outline it will be seen that the establishment of a geophysical laboratory for the serious quantitative study of rock formation encounters its chief difficulties, and therefore applies its greatest effort in the opening years of its development, in the solution of questions of purely physical and physico-chemical origin; that is, in the perfection of its tools; and it is equally interesting to know that the results of these efforts are of equal value to the older sciences.

To carry the discussion further upon these lines would be to exceed the limits of an annual report of progress. It will therefore be better to turn to one of the mineral problems upon which we have been engaged for a considerable time, in which positive conclusions have now been reached which are not only of considerable value to petrologists but also to one of our important national economic interests. As soon as it had proved practicable to establish the relations of two stable minerals throughout all the conditions of change to which they may have been subjected in nature, it became important to know whether the complications introduced by adding a third and eventually a fourth mineral would yield to the same methods of analysis. The complicated character of natural rocks makes this question of the very first importance from the geological viewpoint. A system of three of the most important oxides entering into the composition of rocks—silica, lime, and alumina—has, therefore, been under investigation for a considerable time, and a preliminary report of it is now in press. The scope of such an investigation and some of its difficulties will perhaps be appreciated from the fact that it involves the interaction of fourteen minerals, with the formation of sixteen ternary eutectics. Inasmuch as this is perhaps the first time that a three-component system of silicates has ever been seriously studied from this viewpoint, it is a most interesting and important investigation and hardly admits of concise review. In it we have not only been able to establish the equilibrium relations obtaining in a complicated group of minerals, but we obtain for the first time a true conception of what might be expected to happen when a magma of certain composition is intruded into limestone or sandstone in such quantity that considerable portions of the older rock have redissolved and affected the composition of the magma. It also offers for the first time in laboratory experience a case of resorption of a mineral which formed early in the cooling process, dissolved, and afterward reappeared in other relations in which neither a change of pressure nor any sudden change of conditions interfered to interrupt the cooling process.

This experimental demonstration of resorption becomes of great interest to petrologists in that it bears directly on the classical question of the *order of crystallization* from the magma. In the present instance the first crystals to separate redissolve and disappear in the magma. The true order of crystallization is, therefore, not that which the study of the cold rock would lead one to believe. Furthermore, this relatively simple ternary system affords

experimental demonstration of the fact that the order of crystallization is determined by the composition of the magma and not by the melting temperature of the individual crystals. While such a relation has been predicted by physical chemists from general considerations, this is probably the first time it has been experimentally shown for the more complex silicate magmas. It is likely to prove of immense geological importance in its future application.

PORTLAND CEMENT.

Inasmuch as the three oxides above referred to also form the basis of Portland cement, it has proved possible for the first time in the history of cement study to establish the true composition of cement clinker. It has been shown from what initial compositions the clinker will contain free lime, and that clinker which does not contain free lime can crystallize to one or the other of two different but definite mixtures, depending on the initial concentration. This is also likely to prove of considerable importance, not only in determining what components of Portland cement are essential and what ones are merely accidental, but may also form a basis for establishing standards of pure cement. It also furnishes the basis for a rational explanation of the setting and hardening phenomena of both Portland and slag cements; it will assist in clearing up the many anomalies noted in the practical working of concretes; and, finally, the completed diagram will explain the fundamental nature of blast furnace slag and furnish a sound basis for a study of its mode of action.

In view of the number of measurements to be made where so many relations are involved, the present announcement is preliminary and does not cover the whole ground. The work will be continued during the coming year.

SULPHIDES OF IRON.

Partly in order to ascertain whether physico-chemical methods of analysis would be of assistance in the study of ore deposition, and partly by reason of the economic importance of the sulphides of iron, a laboratory study of pyrite, marcasite, and pyrrhotite was begun nearly three years ago. But here also a difficulty cropped out very early in the investigation, of precisely the same character as the others referred to earlier in this report. Analytical chemistry was unable to provide methods for the determination of the amount of sulphur contained in a given product which were correct within 2 per cent. The investigation was accordingly halted until a method could be developed. This painstaking effort has now been rewarded, and is published in two papers which are reviewed on pages 96 and 97. Determinations of this sulphur can now be made which are accurate within 0.1 to 0.2 per cent.

Continuing upon the original plan, we now find pyrite and marcasite to be different crystal forms of a true compound, FeS_2, the marcasite becoming unstable and going over into pyrite at about 450°. The obvious inference is

that natural marcasite has formed below this temperature. Pyrite has been made at 60° by the addition of sulphur to pyrrhotite, also by the action of H_2S on ferric hydroxide above 100°. Pyrrhotite is found to be FeS plus a variable quantity (over 40 per cent in artificial preparations) of sulphur which is gradually driven out with increasing temperature until the substance melts as nearly pure FeS at 1180°. Troilite, which is formed in a matrix of pure iron, must therefore correspond to the pure compound FeS, which becomes the end member of the series of solid solutions. Pyrite dissociates to pyrrhotite, beginning at about 500°, and the vapor pressure reaches one atmosphere at about 680°. (Review, pages 104, 105.) A definite clue is now established to the conditions of formation of the iron sulphides in nature, and the problem will be pursued further.

This is the first case in our experience with the minerals in which a solid solution has been formed through the direct action of diffusion.

PUBLISHED WORK OF THE YEAR.

Brief reviews of the papers published by the laboratory staff during the year follow:

(1) The intrusive rocks of Mount Bohemia, Michigan. Fred. Eugene Wright. Mich. Geol. Survey, Ann. Rep. 1908, 361.

A study in rock differentiation. The intrusive mass which outcrops on the south side of Mount Bohemia, Michigan, consists of two distinct rock types: (1) a peripheral shell of oligoclase gabbro, abnormal in mineral composition; (2) a central mass of oligoclase gabbro aplite. The contact between the oligoclase gabbro and the intruded ophites of the Keweenaw formation is usually sharp, while that between the gabbro and the aplite is usually of the transitional type. From granularity relations within the aplitic mass itself, it is evident, on Lane's theory of the grain of rocks, that at the time of crystallization of the red aplite the oligoclase gabbro was exceedingly hot; not much cooler, in fact, than the solidifying aplite magma. A consideration of the various possible explanations of the field relation between the gabbro and the aplite favors the theory of separation by fractional crystallization combined with convection currents and general upward movement.

The temperature regions in which the gabbro and the aplite melt in the dry state were found by actual measurement in the Geophysical Laboratory to differ so slightly that no conclusions with respect to a possible eutectic relation between the two could be drawn from the thermal data alone.

(2) A feldspar from Linosa and the existence of soda anorthite (carnegieite). Henry S. Washington and Fred. Eugene Wright. Am. Journ. Sci. (4), 29, 52. 1910.

This feldspar, from the volcano Monte Rosso, on the island of Linosa, east of Tunis, is both chemically and physically abnormal; its composition is very closely Na_2O, 2 CaO, 3 Al_2O_3, 9 SiO_2, while its optic properties indicate a plagioclase of about the composition Ab_3An_2. A detailed discussion of the observed phenomena leads to the conclusion that the Linosa feldspar is a plagioclase, containing about 5 per cent of the molecule Na_2O Al_2O_3 2 SiO_2 (=Cg) in crystal solution, in which case its formula may be written

$Ab_8An_{10}Cg_1$. The molecule $Na_2O\ Al_2O_3\ 2\ SiO_2$ is anorthite in which calcium has been replaced by soda. Crystals of this soda anorthite were first made by S. J. Thugutt, who found that they also resembled anorthite in the thin section. Crystals of this substance have also been made in the Geophysical Laboratory and studied microscopically and the conclusions of Thugutt corroborated. No evidence was obtained opposing the hypothesis of crystal solution. For the Linosa feldspar itself, the name *Anemousite* is proposed, while for the term soda-anorthite, which is open to serious objection, it is suggested that the name *Carnegieite* be substituted, in honor of the Institution under whose auspices the present investigation was undertaken.

(3) The nitrogen thermometer from zinc to palladium. Arthur L. Day and Robert B. Sosman. With an investigation of the metals, by Eugene T. Allen. Am. Journ. Sci. (4), 29, 93. 1910.

It is now something over five years since the Geophysical Laboratory took up the task of redetermining the absolute temperature scale from 300° to 1100° with the nitrogen thermometer, and of extending it, if it should prove practicable to do so, to 1600° C., for in this upper region are found most of the mineral relations which it is the chief purpose of the laboratory to study. Two preliminary publications have been made during the investigation (Phys. Rev., 1907; Am. Journ. Sci., 1908). The present paper extends the earlier observations to 1550°, and completes the work contemplated under the original plan.

No attempt will be made to offer an inclusive summary of the whole investigation. It is a record of experimental measurements covering an unusually wide range of details which do not admit of brief classification. The errors which have heretofore been present in measurements with the nitrogen thermometer have been reduced by the present investigation to about one-fourth their former magnitude, and the certainty of their evaluation is at least proportionally increased. Careful analyses were made of all the metals used as standards.

The chief source of present uncertainty is the temperature distribution over the surface of the bulb in an air-bath. No indication of a limit to the temperature attainable with the nitrogen thermometer or to its ultimate accuracy was discovered during the present investigation.

The melting temperatures of the metals and salts which have been used as fixed points to establish the new scale are brought together in the table below. To this table has been added a new estimate of the melting temperature of platinum, obtained by adding the optically determined difference between the melting points of palladium and platinum to our determination of the palladium point.

Cadmium	320.0 ± 0.3	Diopside (pure)	1391.2 ± 1.5
Zinc	418.2 ± 0.3	Nickel	1452.3 ± 2.0
Antimony	629.2 ± 0.5	Cobalt	1489.8 ± 2.0
Aluminium	658.0 ± 0.6	Palladium	1549.2 ± 2.0
Silver	960.0 ± 0.7	Anorthite (pure)	1549.5 ± 2.0
Gold	1062.4 ± 0.8	Platinum	1755.0
Copper	1082.6 ± 0.8		

(4) High-temperature gas-thermometry and its present limitations. Arthur L. Day. Metall. and Chem. Eng., VIII, 257. 1910.

A brief review of recent progress toward the establishment of trustworthy reference temperatures in the region between 1000° and 1600° C., for the information of engineers.

(5) Some mineral relations from the laboratory viewpoint. Arthur L. Day. Bull. Geol. Soc. Amer., 21, 147. 1910.

Until recently, petrologists have confined their attention largely to the collection and examination of the field and microscopic evidence bearing on the rocks and their mode of occurrence, while the more precise quantitative methods of attack have been slower in development and are only now beginning to be considered seriously. This is especially true of experimental evidence, and one of the chief purposes of this paper is to invite the consideration of geologists, or more particularly, of petrologists, to certain phases of the problem of rock formation as they begin to appear from the viewpoint of the laboratory investigator.

The laboratory student, for example, proceeding from the physical standpoint, recognizes melting or crystallization as a "change of state" involving, according to accepted molecular theory, a complete change in the molecular structure of the substance. Such a change will carry with it various visible evidences of its occurrence, as, for example, the appearance or disappearance of crystal structure; a change of density; a change in the electrical conductivity; in the case of melting, a more or less sudden appearance of fluidity causing it to take the shape of the containing vessel; a change in the specific heat—in a word, there appears a more or less conspicuous discontinuity in all its physical properties. If we would therefore determine the crystallizing or the melting temperatures of a great body of substances, it is not merely necessary to be able to measure temperatures accurately and conveniently, but also to obtain sufficient knowledge of the individuality of the substances under investigation to enable us to be quite sure that the method employed for detecting the change of state when it occurs is an appropriate one for each particular substance. Any method which allows considerable latitude to the judgment of the observer will fail, as it has done heretofore, to yield uniform and therefore trustworthy results on which to base serious geological conclusions.

The effect of small quantities of by-mixtures in lowering formation temperatures and the importance of the volatile constituents which have participated actively during all the earlier stages of rock formation but of which only significant traces are now found, can be determined only in the laboratory. It is through the study of the volatile constituents also that one of the chief effects of pressure as a controlling force in rock formation has been brought to light; the pressure serves to retain these fugitive ingredients.

Laboratory experience, and in particular the study of simple two-component mineral solutions from the viewpoint of physical chemistry, throws much light on the order of crystallization of minerals from the magma. Physical chemistry distinguishes but two general modes of formation: (1) the eutectic series, in which the excess component first appears separately, followed by a mixture of both in fixed proportions, called the eutectic; (2) the isomorphous series, in which the two components always appear together, the first crystals to form being usually considerably richer in the higher melting component, followed in gradually changing proportions by mixtures of lower melting-temperature. When the number of component minerals is greater than two, the situation of course becomes more complicated, but the two modes of formation above indicated are perfectly general and cover the whole ground. The establishment of the fact that such generalizations of physical chemistry find application to mineral mixtures is of particular interest from the viewpoint of the older petrology, for it appears at once that a particular mineral, magnetite for example, does not necessarily take prece-

dence over all others in crystallizing out of the magma; magnetite will be the first to crystallize only when it is present in excess of the quantity which can be carried in that particular solution at the temperature and pressure which chance to prevail there.

In the development of laboratory methods in the service of petrology, one in particular has opened a new field of considerable significance. The ability to detect and locate extremely small energy changes in a cooling or heating system makes it possible to establish inversion temperatures with certainty. These inversions, or changes of crystal form in the solid state, are peculiarly independent of neighboring minerals, or of volatile ingredients, and therefore often serve to determine the temperature region in which a particular natural mineral must have formed. Such inversions appear to be considerably more numerous than has hitherto been supposed, and when established in sufficient number form a kind of geologic thermometer which can be easily and generally applied in the field.

(6) A new petrographic microscope. Fred. Eugene Wright. Am. Journ. Sci. (4), 28, 407. 1910.

Experience has shown that in microscopic work with artificial silicate specimens special methods and apparatus are necessary, and to meet these requirements a special microscope has been constructed. Its most important features are: (1) Both nicols revolve simultaneously, the connection between the two being a rigid bar, thus eliminating the errors due to lost motion in the gear wheels ordinarily employed for this purpose. (2) The upper nicol remains in the tube and the nicols are crossed by inserting the substage polarizer. This arrangement eliminates the annoying change of focus, and therefore of field, ordinarily experienced on insertion of the upper nicol. (3) The sensitive plate is introduced just below the condenser and fits in a carrying device which can be rotated about the axis of the optical system. This disposition has been found convenient in determining the relative ellipsoidal axes in a crystal section, since the sensitive plate can be rotated more quickly than either the microscopic stage or two nicols together. (4) A mechanical stage of novel design and simple but effective mechanical construction. The stage is practically dust proof and has a free upper plate with a movement of 24 mm. in any direction. (5) The Bertrand lens is fitted with a sliding device by means of which the magnification of interference figures can be varied from 6.5 to 15.2 diameters. For the purpose of bringing an interference figure to sharp focus in the plane of the iris diaphragm immediately below the Bertrand lens, a small auxiliary lens is used in conjunction with the ocular. This lens is attached on a swinging arm and can be thrown in or out of the field at will without disturbing the eyepiece. (6) A second iris diaphragm occurs just below the eyepiece and serves in place of the cap diaphragms now used in observation of interference figures after the Lasaulx method without the Bertrand lens. (7) A large Abbe condenser is used, together with an Ahrens prism of 15 mm. edge, or with a large Glan-Thompson prism, in place of the usual nicol and condenser system with removable upper lens.

(7) A new ocular for use with the petrographic microscope. Fred. Eugene Wright. Am. Journ. Sci. (4), 29, 415. 1910.

This ocular consists of a Ramsden eyepiece and three mounted edges or plates, *a, b, c,* which are inserted in the focal plane of the eyepiece, and by means of which the following three fundamental optic properties of minerals

in the thin section can be measured: (1) with the graduated combination quartz wedge *a*, the birefringence; (2) with the ruled plate *b* (interval of cross-section ruling, 0.1 mm.), the optic axial angle, provided one or both optic axes appear within the field of vision; (3) with the bi-quartz wedge plate *c*, the extinction angle. These three features, and particularly the first two, are usually estimated only roughly and not measured accurately in petrographic work, because of the complicated apparatus hitherto required for the purpose. The present ocular was designed to serve as a simple but effective substitute for such apparatus and thus to facilitate the actual measurement of these important properties.

(8) The exact determination of sulphur in soluble sulphates. E. T. Allen and John Johnston. Journ. Am. Chem. Soc., 32, 588. 1910.

The errors in the determination of sulphur in soluble sulphates have been investigated for those cases which most frequently occur in experimental work. Solutions of sodium, potassium, ammonium, and magnesium sulphates have been studied, both in a state of purity and in the presence of varying quantities of hydrochloric acid and alkali chlorides. In a few systems the influence of sodium nitrate has also been studied.

The most important sources of error are three in number, one arising from the solubility of the precipitate and the others from its composition. Two minor sources may also be mentioned.

(*a*) The error from solubility depends chiefly on the quantity of free acid present. Contrary to the common belief, we find that the chlorides of sodium, potassium, and ammonium exercise a hardly appreciable influence on the solubility. Under easily regulated conditions (0.2 cc. 20 per cent HCl in 350 cc. original solution) it amounts to 1 to 2 mg. only. It is self-evident that this error (almost negligible for precipitates of 1 gram or more) becomes increasingly important, the smaller the precipitate.

(*b*) All barium sulphate precipitates carry down with them quantities of the alkali sulphates, varying with many conditions. In the case of pure acidulated sulphates this quantity is not far from 0.5 per cent. It is especially affected by alkali chlorides and may be more than doubled in this way. The correction depends of course on the atomic weight of the alkali metal. About 0.75 per cent is the maximum quantity of ammonium sulphate absorbed by precipitates under conditions which have been investigated by us; the correction for it is, however, comparatively large (1.25 per cent), because ammonium sulphate is entirely volatilized when the precipitate is ignited. Magnesium sulphate is scarcely absorbed at all by barium sulphate. The peculiar selective absorption exhibited by barium sulphate suggests the formation of solid solutions. The evidence on the subject is, however, too meager for a proof.

(*c*) Barium sulphate, when precipitated from alkali sulphates, always occludes a certain amount of "free" sulphuric acid, which is probably taken up as acid sulphate of the alkali metal. It arises, of course, from the free acid added to the original solution and increases with it up to a certain point. Alkali chlorides decidedly increase the amount of it, and in the presence of much of the latter it becomes the chief source of error. Aside from one or two qualitative observations, this loss seems to have been thus far entirely overlooked. It is greater for potassium than for sodium sulphate solutions. In one case a solution of the former containing 10 grams KCl and 5 cc. 20 per cent HCl in 350 cc. lost 1.7 per cent in this way.

(*d*) All barium sulphate precipitates contain barium chloride. If the precipitation is made slowly (3 to 6 minutes for 2 grams $BaSO_4$), the amount of this is only about 0.15 per cent in the unignited precipitate, and since all but a trace of it is eliminated as hydrochloric acid during ignition it is not a source of error. When a precipitate is very rapidly formed the amount of the barium chloride is multiplied several times and the chlorine is no longer entirely eliminated on ignition. The more rapid the precipitation, the finer the precipitate, and, since the barium chloride retained increases with the fineness, we regard it as probably held by adsorption. The other impurities are diminished by rapid precipitation.

(*e*) Sodium nitrate, and probably other nitrates also, are occluded by barium sulphate, giving results which are therefore too high.

An exact determination of sulphur, so far as we know, can only be done by correction for the above-named errors. Nitrates are to be avoided; also chlorides and ammonium salts as far as possible. Corrections for occlusion and solubility can be made directly, but for volatility, unless one has a specially constructed platinum apparatus, a duplicate precipitation must be made under identical conditions.

The error which led us to make this investigation, and which must be expected if these precautions are neglected, not infrequently reaches 2 per cent. A carefully corrected determination of sulphur for the cases given should be accurate to 0.1 to 0.2 per cent *of the total sulphur.*

(9) The exact determination of sulphur in pyrite and marcasite. E. T. Allen and John Johnston. Journ. Industrial and Eng. Chem., vol. 2, 1. 1910.

It has been shown that when the sulphides of iron are ground for analysis they suffer partial oxidation to sulphur dioxide and ferrous sulphate. If they are finely pulverized this error is not negligible; it may be reduced to 0.05 per cent by gently crushing to 20-mesh size, which is sufficiently fine for the proposed method of analysis. Inhomogeneous material, such as would be met with in commercial work, would have to be pulverized for the purpose of accurate sampling. In that case the error could be determined by washing a weighed portion of the powder with boiled water in an atmosphere of carbon dioxide and determining the iron in the washings; the operation is rather exacting on account of the readiness with which the moist sulphide oxidizes.

In the proposed method the sample is oxidized in sealed tubes, according to Carius; this avoids all possible loss of sulphur. Lunge's and even Fresenius's method gave in our hands lower results, a fact which we attributed to a loss of sulphur during oxidation, occasioned by the use of coarse material, or perhaps, in Fresenius's method, to the presence of iron in the barium sulphate.

The iron is removed by two precipitations with sodium carbonate. The object of this is to avoid ammonium salts, which cause much larger losses of sulphur. In precipitating the barium sulphate, the conditions described in the previous article should be followed. The sum of the errors in the method, apart from that involved in the grinding, should not be over 0.2 per cent *of the total sulphur.* The extreme variation in our own analyses was less than 0.15. Incidentally, it was learned that the precipitation of iron by ammonia involves much larger errors than has been generally supposed, if, as is customary, the ammonia is kept in glass bottles and the precipitation is made in glass beakers.

(10) Neutral contacts and switches. (Abstract.) Walter P. White. Phys. Rev., 30, 784. 1910.

By neutral contacts is meant contacts free from electromotive forces, due to small temperature difference. Such contacts are often advantageous and can usually be obtained with ease where extremely low resistance is not necessary. One simple way of obtaining them is to make the contacts between very thin strips of homogeneous metal. Contacts of this type can easily be given a wide variety of forms, some of which, besides their superiority in the matter of electrical results, are much more convenient and cheaper than forms now in common use.

(11) The relation between zero shift and size of wire in the moving coil galvanometer. (Abstract.) Walter P. White. Phys. Rev., 30, 782. 1910.

The displacement of the zero usually produced by the deflection of a moving coil galvanometer is at present one of the most serious sources of inconvenience or error with that instrument. It is due to magnetic impurity in the coil and to irregularity of the magnet field, and the entire avoidance of these two defects is practically impossible. Hence it is worth while to consider how their effect may be diminished. The paper shows that for given magnetic defects the zero shift increases with the sensitiveness and also with the shortness of period, but diminishes when period is shortened at the expense of sensitiveness; for a galvanometer of given performance it increases with the amount of dead material in the coil, and very rapidly with the size of wire. Hence low resistance, which necessitates large wire, increases zero shift, and an unnecessarily low resistance is decidedly detrimental. Hence, also, in ballistic work it is often better to get long periods by using wide coils than by loading narrow ones.

(12) Heizmikroskope. Arthur L. Day and Fred. Eugene Wright. Centr. f. Min., etc., No. 13, 423. 1910.

A brief answer to certain criticisms by C. Doelter (Vienna) of the new thermal microscope constructed in the Geophysical Laboratory. The appearance of the criticism seemed to afford a favorable opportunity to explain some of the advantages of this instrument for use in quantitative research work, when compared with earlier instruments employed for a similar purpose.

(13) The platinum-rhodium thermoelement from 0° to 1755°. Robert B. Sosman. Am. Journ. Sci. (4), 30, 1. 1910.

In continuation of the recent work from the Geophysical Laboratory on the nitrogen thermometer from zinc to palladium (see page 93), the interpolation curve of the thermo-element Pt–(90 Pt 10 Rh), has been extended downward to 0° and upward to the melting-point of platinum. The value of the melting-point of platinum obtained by extrapolation of the curves of a number of thermo-elements containing from 1 to 15 per cent rhodium confirms the value previously adopted (1755°) within the estimated limit of 5°. A simple method of interpolating temperatures with the 10 per cent thermo-element by means of a standard curve and deviation curves is described in the article.

The variation of thermal E. M. F. with the temperature and composition of the platinum-rhodium alloy wire has been determined. The variation,

both with temperature and with composition, is, within the limits of error, continuous over the entire range studied. The variation of thermo-electric power $\frac{de}{dt}$ with the temperature and composition of alloys of platinum and rhodium indicates the formation of solid solutions, but no compounds, from 0 to 55 atomic per cent of rhodium.

(14) The thermo-element as a precision thermometer. Walter P. White. Phys. Rev., 31, 136. 1910.

The thermo-elements used in some of the calorimetric work of the laboratory have proved surprisingly convenient and accurate. The value of the thermo-element for work of this kind has been but little appreciated; hence a discussion is given of its construction, of some methods for increasing the precision attainable, and of its value for different purposes. The following summarizes the principal conclusions reached:

(1) The E. M. F. of a thermo-element, whether homogeneous or not, can be expressed as equal to $\int H d\theta$ (H=thermo-electric power, θ=temperature). It follows that the effect of each portion of a thermo-element is proportional to the magnitude of the temperature gradient in which it lies; hence the vital parts of a thermo-element are the parts along which the temperature varies; they mainly determine the calibration and the constancy; with them alone need the maker or user of the thermo-element be concerned. In changing them (for example, by varying the depth of immersion in a furnace) the thermo-element itself is changed, if not homogeneous. Such changes in regions of uniform temperature distribution (for example, at the junction) have little effect on the temperature measurement.

(2) Commercial constantan wire, good enough to make thermo-elements which are accurate to about 0.05 per cent, is easily obtained and costs but little trouble in the selection, but can not be relied upon without any test for possible inhomogeneity. Compensated thermo-elements of higher accuracy, reading consistently to 0.0001°, for use at ordinary and low temperatures, can be made up in a day or two each. Improvement in the accessory apparatus has shown that their constancy is about ten times that shown three years ago.

(3) The accuracy of 0.0001° reached by the thermo-element can also be attained in its auxiliary apparatus (potentiometer, etc.). This accuracy, both absolute and relative, and the sensitiveness are therefore quite comparable with those of the best resistance thermometers now in use.

(4) For the measurement of single temperatures, the resistance thermometer is often more convenient. On account of the comprehensiveness of the potentiometer and its indifference to external contact resistances, the thermo-element is usually preferable where several different measurements are to be made at once. The thermo-element is also usually superior for differential measurements, and its advantages in this respect can be made available for calorimetric work by the substitution of a suitable comparison body for the usual ice bath.

(5) A very convenient wire-tester, a simple bath for testing and comparing thermo-elements, and a convenient form of tabulation for calibration curves are also described.

(15) The calibration of copper-constantan thermoelements. Walter P. White, H. C. Dickinson, and E. F. Mueller. Phys. Rev., 31, 159. 1910.

Through the courtesy of the Director of the U. S. Bureau of Standards, some thermo-elements from the Geophysical Laboratory were calibrated at the Bureau and afforded a favorable opportunity for the study of the general properties of these thermo-elements in direct comparison with resistance-thermometers for low-temperature measurements of great precision. The result of the calibration is given here. Some of the advantages and disadvantages of thermo-elements for this work have been outlined in the preceding abstract (14).

A pair of copper-constantan thermo-elements for use in calorimetric work was calibrated by comparison with standard resistance thermometers to an accuracy of 0.004°. It is probable that the accuracy of the calibration could be considerably increased if need be. A cubic equation represents the relation between the temperature and electromotive force, in the interval 0° to 100°, with an accuracy of 0.005° or better. The resistance thermometers were read to 0.001° and the thermo-element to 0.003°, the difference in sensitiveness being practically due to the difference in the galvanometer used.

(16) The thermal dissociation of calcium carbonate. John Johnston. Journ. Am. Chem. Soc., 32, 938. 1910.

In all previous measurements of the equilibrium pressure of the reaction $CaCO_3 \rightleftarrows CaO + CO_2$, the errors have been due mainly to a lack of definiteness in the temperature of the reacting system. In the experiments described in this paper, which extend over a temperature range of about 300°, this difficulty was obviated by the use of an improved form of apparatus, which, with a total vapor space of not more than 5 cc., required only 0.1 gram of substance. With this arrangement, the temperature of the charge was easily kept uniform, and was determined with an accuracy of ± 2° at 900° C. The results of these measurements are well reproduced by the equation:

$$\log p = -9340/T + 1.1 \log T - 0.0012\,T + 8.882$$

where p is the equilibrium pressure (expressed in millimeters of mercury) at the absolute temperature T. The pressure reaches one atmosphere at 898° C. The above formula was deduced from thermodynamic considerations; accordingly it may be used with some confidence for obtaining the pressures corresponding to temperatures above 900° C., the extrapolated values being more reasonable than those obtained by the use of the formulas previously proposed by others.

(17) A new occurrence of plumbojarosite. W. F. Hillebrand and Fred. Eugene Wright. Am. Journ. Sci. (4), 30, 191. 1910.

A brief description of the crystals of this mineral from American Fork, Utah. Its observed optical and chemical properties agree well with those of plumbojarosite from Cooks Peak, New Mexico.

(18) The transmission of light through transparent inactive crystal plates. Fred. Eugene Wright. Am. Journ. Sci. (In press.)

An investigation into the influence of the boundary surfaces of inactive transparent crystal plates on transmitted light-waves. The problem of refraction and reflection of light on crystal plates was first solved successfully in a general way in 1835 by F. E. Neumann in Germany and by J. MacCul-

lagh in Ireland. The work of these two investigators was remarkably thorough and comprehensive and has served as the foundation on which all subsequent researches have been based. Interest, however, has centered chiefly in the reflection rather than in the refraction of light by crystal plates, and much still remains to be accomplished on the details of the refraction problem. The present investigation was undertaken primarily to determine the influence of certain factors which underlie the methods of optic axial-angle measurement of crystal plates in the thin section, especially the method of Professor Becke and Wright's modification of the same. These methods are based on the degree of curvature of the dark hyperbolas or zero isogyres of the interference figure, and depend, therefore, on the polarization direction of light-waves transmitted along different paths. In microscopic work, the influence of the boundary surfaces, not only of the crystal plate but also of the intervening glass plates and lenses, on these waves enters the problem and tends to render it exceedingly complicated. In this paper the general mathematical treatment of the problem of light transmission through transparent inactive crystal plates is given and several new and important relations are deduced which simplify the presentation materially. The results of calculation are checked by series of observations on plates of calcite, muscovite, selenite, and quartz, with apparatus specially designed for the purpose. The results of the investigation show that the methods proposed by Professor Becke and by Wright are approximate methods only; both furnish results of about the same order of accuracy, the single advantage of Wright's method being that of slightly greater simplicity. They show, furthermore, that a theoretically correct method is not practicable, because of the many complicated factors of only slight influence which would have to be taken into consideration. Incidentally, the general effects of lenses on interference figures are discussed; also the construction of nicol prisms and the adjustment of the petrographic microscope.

This rotating effect of the boundary surfaces on the planes of polarization of transmitted light-waves underlies all observations involving the use of convergent polarized light or of parallel polarized light entering the crystal plate at angles with the normal. The influence is only slight in any case, but it precludes a high degree of accuracy in any measurements based on such phenomena. Methods involving the use of interference figures or of the universal stage, although of great practical value, are only approximate methods, and, because of the complexity of the factors involved, can not be modified so as to be theoretically correct. The direct application of Fresnel's rule for finding the planes of polarization of transmitted waves is, in such cases, not strictly correct; but experience has shown that the error introduced thereby is not greater than that resulting from other causes and is therefore permissible.

(19) Some glacial effects of ice action in Iceland. Fred. Eugene Wright. Bull. Geol. Soc. Amer. 1910. (In press.)

A study of the physiographic features developed by glacial erosion with special reference to the difference between valley glacier erosion and that of the continental ice sheet on the uplands, the one tending to develop downward rather than laterally, and to accentuate differences in elevation, the other serving as a plane of reference toward which exposed masses tended to be reduced, the ultimate result of its action being to truncate all mountain masses at a common level, the upland surface thus produced strongly resembling in appearance an uplifted and dissected peneplain.

(20) Preliminary report on the ternary system CaO-Al_2O_3-SiO_2: A contribution to the study of the constitution of Portland cement clinker. E. S. Shepherd and G. A. Rankin. With optical study by Fred. Eugene Wright. Am. Journ. Sci. (In press.)

In this paper the general limits for the different solid phases of the ternary system have been established and a few of the quintuple points located. A new form of calcium orthosilicate has been discovered. From the ternary diagram it follows that relatively slight changes in the initial composition of the raw material will bring about relatively large changes in the composition of the clinker. That is, the crystal phases present in the clinker will be very different, depending on the initial concentration of the charge from which it is made. It remains to be shown whether these different varieties of clinker will show appreciable differences in properties when used for making cements.

(21) Some calorimetric methods. Walter P. White. Phys. Rev. 31, 545. 1910.

The work on silicate specific heats has led to the development of new apparatus, and of methods, some of which differ radically from those hitherto generally accepted as best. A description of these new features, an examination of the principal errors in calorimetry, and of the accuracy attained by different methods, together with a report of an experimental test confirming the conclusions reached, are given in this and the following three papers.

1. The oft-noted uncertainties in the calorimetric cooling correction are usually due to changes in room temperature and to evaporation. For the greatest accuracy, and usually for convenience also, it is well to have: (1) a jacket whose temperature is measured directly, completely surrounding the calorimeter; (2) the calorimeter cover in contact with the water, so that all bodies at uncertain temperatures are avoided; and (3) evaporation made very small. The difficulties of the cooling correction then largely disappear.

2. With this system the method of computing the cooling correction often requires but one cooling period, and about one minute's arithmetical work after observations are finished. The method is especially advantageous where bodies are dropped into the calorimeter.

3. Ordinarily, in accurate calorimetry, a very small temperature interval is used, in order that the observer may have the advantage of assuming Newton's law of cooling in his computations. This magnifies the effect of thermometric errors. To make a correction for the variation from Newton's law increases accuracy in most cases without increasing appreciably the labor of computation. The procedure is this: Since the cooling rates are not proportional to the temperatures, the temperatures are simply corrected so as to be proportional to the rates; all the ordinary formulæ can then be applied. For ordinary accuracies, the correction can be disregarded up to 8°. With the correction, deviations from Newton's law cause no error in 20° intervals.

4. If a small interval is necessary, the preceding method can not be applied. The required absolute accuracy in temperature measurement can then usually be obtained by electrical methods, but with these, as usually conducted, the electrical quantity measured corresponds to a relatively large temperature interval (20° to 300°), so that great precision is required. This difficulty is avoided if, with the thermo-element, the customary ice bath is replaced by a comparison body in a water-jacket. The correction for its change is only a cooling correction, and does not materially affect the total error, since the regular calorimeter necessarily has a larger and more uncertain correction of the same kind, or something equivalent. The net gain is

a considerable simplification of the problem of accurate temperature measurement, where intervals and not absolute temperatures are required.

(22) Lag effects and other errors in calorimetry. Walter P. White. Phys. Rev. 31, 562. 1910.

1. In calorimetry, the error from thermometric lag is rigorously zero for the assumptions usually made as to the lag of the thermometer, as long as one thermometer is used throughout.

2. Other lags, in the water, in the metal parts of the calorimeter, and in the surrounding air, are all proportional to the total temperature rise, are wholly or largely independent of the rate of heating, and are, moreover, so small as to be usually quite negligible in any case.

3. The real sources of error lie in (1) temperature measurement; (2) lack of uniformity in temperature, especially of the jacket; (3) variation in the heat of stirring; (4) variation in evaporation.

Of these, (1) is the most serious. An increase in the temperature interval diminishes it proportionately, and such increase is at present one of the most effective methods available for increasing accuracy.

Complete avoidance of (2) requires absence of large projecting masses, a calorimeter cover in contact with the water, thorough stirring of the jacket water, and a complete inclosure by the jacket.

Appreciable error from the heat produced by stirring (3) can always be avoided. In some cases this may require a governor for the stirrer, but usually it will not. The heat increases about as the cube of the speed, hence an unnecessarily high speed is very detrimental. The error is probably less for small calorimeters. The opinion that propellers give more heat than reciprocating stirrers, for the same efficiency, needs re-examination.

Evaporation from the calorimeter water (4) can be made regular within a complete inclosure, if this is not too small.

4. With proper precautions, the cooling correction, contrary to common opinion, is not at present an appreciable source of error. Special methods which aim to increase accuracy by diminishing the cooling correction are, therefore, not likely to be very effective, though they may be convenient.

(23) Some calorimetric apparatus. Walter P. White. Phys. Rev. Dec. 1910. (In press.)

This paper deals with a calorimetric system in which all conditions affecting the calorimeter temperature are, as far as possible, definite and measured and in which, as a result, errors once serious are made negligible, computation is often simplified, and an increase in effective thermometric accuracy can be secured. The apparatus was designed for the determination of specific heats, especially at high temperatures, by the mixtures method.

1. Two calorimeters are described, designed for effectiveness in stirring. In one of them the use of an *inclined* central tube affords a path both wide and short for the circulating water, and at the same time allows the stirrer itself to remain simple. Copper covers, carefully fitted and in contact with the water, practically eliminate evaporation, both externally and internally. When in their jacket, these calorimeters are surrounded above and on all sides by a single compact body of circulating water and therefore have a uniform environment. The calorimeter chamber can be opened at any time without disturbing either the circulation or the connections to the calorimeter.

2. Furnace: The internally-wound type of furnace commonly used in the Geophysical Laboratory, modified to permit the dropping of bodies, was used for most of the temperatures employed. At 1500° the temperature of the charge was uniform to a small fraction of 1 per cent.

3. A light swinging shield under the furnace controls the exposure of the calorimeter. It performs with certainty, ease, and quickness the functions often sought through a movable calorimeter or furnace.

4. Temperatures uniform and constant to 0.1° at least are obtained for the interval from 200° to 600° in an electrically heated and stirred bath of melted metal, which surrounds but does not touch the body to be heated.

5. A steam-heated oven is also used. With this a simple automatic arrangement gives uniformity of results in dropping bodies into the calorimeter.

6. This paper makes a short addition to a previous discussion of equipotential leakage shields. By partly inclosing the apparatus in cases which also contain drying material, and then coating with paraffine all exposed insulating surfaces, insulation was assured, without inconvenience, under atmospheric conditions previously considered almost fatal to high accuracy in the measuring system.

(24) A test of calorimetric accuracy. Walter P. White. Phys. Rev. Dec. 1910. (In press.)

The two calorimeters described in the previous paper were calibrated by the electrical method, and the determinations were varied considerably, so as to afford information as to the errors present.

An automatic switch which started and stopped the heating current in obedience to electric signals from a chronometer was an advantageous substitute for a chronograph; otherwise, the details of the calibration were much as usual. The results were:

1. The average accidental error of a complete calorimetric determination has been reduced to about one part in 30,000; the systematic variations under rather diverse conditions were no greater than 0.0002. The essential conditions for this performance appear to have been: (1) ordinary care in manipulation and observing, (2) an electrical thermometer reading consistently to 0.0003°, (3) auxiliary electrical apparatus accurate to 0.00003, (4) a complete and uniform inclosure of the calorimeter, (5) regulation of the stirring, (6) elimination of evaporation, and (7) the use of unusually large temperature intervals. Of these features, only the last two are specially characteristic.

2. The average accidental temperature error was brought below 0.00025°. This is practically a perfect performance for the multiple thermo-element used as a thermometer.

3. No error due to the cooling correction could be detected, even where the total average error was only 0.00003.

4. The preponderant calorimetric error was in the temperature measurement.

5. The use of a large temperature interval obviously diminishes the effect of the temperature error. It brings no corresponding disadvantage. Intervals much larger than those ordinarily used are therefore to be recommended where accuracy is desired.

(25) The sulphides of iron. E. T. Allen, John Johnston, and J. L. Crenshaw. Crystallographic study by E. S. Larsen. Am. Journ. Sci. (In press.)

1. Pyrrhotite has been prepared in the massive form by the decomposition of pyrite or by heating sulphur and iron together to a temperature of about 700°. The dissociation of pyrite into sulphur and pyrrhotite begins very slowly about 500°, and the vapor pressure (judging by the strong heat absorption) reaches one atmosphere at about 680°. The change is reversible

under proper conditions. Measurable crystals of pyrrhotite have been formed by the action of H_2S on ferrous salts at temperatures between 75° and 200°. As proved by others, pyrrhotite undergoes a transformation at about 138°. Products of varying composition were obtained by heating fused material, coarsely powdered, to different temperatures in H_2S and then cooling in nitrogen; they ranged in composition from 36.86 per cent to 39.49 per cent of sulphur. In H_2S all products melt at about 1180° where the composition approaches FeS, though rather more than 2 per cent of sulphur is tenaciously retained. In color and behavior toward hydrochloric acid, the products agreed with natural pyrrhotite. The specific gravity varied from 4.769 to 4.598. The specific volume plotted against composition (percentage of S over the ratio Fe : S = 1 : 1) is practically a straight line. This indicates that pyrrhotite is a solid solution of sulphur in FeS, and troilite is simply the FeS end of the series, without excess of sulphur because it was formed in a matrix of metallic iron. Experiments on the crystal form of pure FeS and on the influence of the vapor pressure of sulphur (dissociated H_2S) on the composition of pyrrhotite are still in progress.

2. Marcasite and pyrite: Marcasite has been synthesized at temperatures of about 200° by the action of H_2S on ferric salts. Measurable crystals showing the proper axial ratio and striations demanded by orthorhombic symmetry were obtained. Some pyrite always seems to form at the same time. Pure pyrite has been obtained by the addition of sulphur to pyrrhotite and also by the action of H_2S on ferric hydroxide above 100°.

Marcasite is an unstable form passing into pyrite with evolution of heat. The lowest temperature at which the change can be detected is 450°. Even in the presence of sulphuric acid none takes place at 350°. The inference is that all marcasite has formed below 450°. It has not proved possible to change marcasite by pressure, cold and dry, at 10,000 atmospheres. It is not improbable, however, that this pressure would change marcasite into pyrite at temperatures lower than 450°. Stokes's method was used for the identification of marcasite and pyrite.

Pyrite seems to be stable (away from the air) up to about 500°, where, in an atmosphere of H_2S, it begins to lose sulphur. In the presence of free sulphur (or dissociated H_2S) it is evident that the point of dissociation would depend upon the pressure and might, in deep-seated magmas, be much above 500°.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. Franklin Jameson, Director.

The following report, the fifth annual report of the present Director, covers the period from November 1, 1909, to October 31, 1910. The regular staff of the Department has remained unchanged throughout the year, consisting of the Director, Mr. Leland, Miss Davenport, and Dr. Burnett. In addition, the Department has had, through most of the year, January to October, the aid of Mr. David W. Parker, and at various times from March to October that of Mr. Leo F. Stock.

Almost from the beginning of the year reported upon, namely, from the middle of November 1909, the Department has enjoyed the use of quarters much more ample than those which it had hitherto occupied. The suite consists of seven rooms in the Bond Building, a part of the suite formerly occupied by the offices of administration of the Institution. Two of them are dark rooms, available only for storage. The other five, however, are of good quality and open conveniently from one to another. The largest room, that formerly occupied by the President of the Institution and used for the meetings of the Executive Committee, is now used as the office of the Director and the place of deposit of the Department's library. Of the others, one is specifically devoted to the records and other papers of the Department and to the work of the secretary; the rest are occupied by the various other members of the staff. The rooms are suitably furnished, but without effort at anything beyond simplicity. They afford sufficient space for our present work, in which we were crowded in our former quarters; but they are much exposed to noise and dust, and are injuriously remote from the Library of Congress; there is also a certain want of dignity, for a branch of an institution of learning, in the associations of an ordinary business building.

From the latter part of June until the latter part of September the office work of the Department was in the main carried on elsewhere than in Washington, part of the staff working at North Edgecomb, Maine, part of it in Cambridge and Boston.

For statements respecting the general plans of the Department and the purposes which its operations are intended to subserve, the Director begs leave to refer to former reports, and confines the present report to statements respecting the progress of specific publications and other undertakings. The publications of the Department, as has been explained in previous reports,

* Address, 500 Bond Building, Washington, D. C. Grant No. 603. $22,700 for investigations and maintenance during 1910. (For previous reports see Year Books Nos. 3–8.)

fall naturally into two classes, the one that of reports, aids, and guides; the other that of textual publications of documents. Under these two heads, and a third relating to the miscellaneous activities of the Department, the work of the past year and the plans for 1911 will be successively considered in this report.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

During the past year one book of considerable magnitude has been published by the Institution for this Department, a "List of documents in Spanish archives relating to the history of the United States, which have been printed or of which transcripts are preserved in American libraries," prepared chiefly by Dr. James A. Robertson, now librarian of the Philippine Library in Manila. Dr. Robertson's departure for Manila in January, to take this new post, caused some delay in the proof-reading of this volume, which did not appear till August. The reasons for preparing the work, and for thinking that it would be of value to American historical workers, were sufficiently set forth in my last report. The entries are arranged chronologically, in two divisions, the one listing those documents which may be found in print, the other those which may be found in the form of transcripts in any American collection accessible to the public. These entries give the date of the document, its title, or in the case of a letter the names of writer and person addressed, the place of the original in the Spanish archives, the place or places where it may be found in print, or a proper reference for finding the transcript or transcripts. There are 5,332 such entries. All this information, guiding to a great amount of material important to United States history, is presented in the most compact form consistent with perfect clearness.

Since the book is technically a list and not a calendar, that is to say, since it does not present analyses of the letters and documents referred to, its index can not be to any large extent a subject-index, though subject-indexing has been carried out where practicable. It is chiefly an index to names of writers and persons addressed. Even so, its preparation was a formidable piece of work, carried out with much skill by Miss Helen C. McGown.

It is worth while to take this occasion to point out that the publications of the Department of Historical Research, publications filled with details, and largely consisting of data relative to individual persons, places, and events, call for much more elaborate indexes than are needed in most publications of other departments, and that the preparation of indexes must have a noteworthy place in the Department's work, consuming a considerable amount of time.

Of the other publications which have been in preparation during the year, that which is farthest advanced toward issue is Prof. Carl R. Fish's "Guide

to the materials for American history in Roman and other Italian archives." At the date of this report its page-proofs have been received and read and the making of the index has been begun. This process has been intrusted to Mr. Stock, formerly a student of the Catholic University of America and well qualified for its execution. The book will be a volume of about 300 pages, providing guidance to a most diversified and interesting body of materials relating to American history, both civil and ecclesiastical. The main portion of the contents is, inevitably, that which deals with the Vatican archives, including the so-called Archivio Segreto, now freely thrown open to investigators, the archives of the secretary of state, rich in reports and documents from the Papal nuncios at various European courts, and a variety of minor subdivisions and collections. But besides the Vatican archives properly so called, and the manuscripts of the Vatican Library, there are many other ecclesiastical archives and collections in Rome. Some of them are connected with the central administration of the Papal government, such as the archives of the congregations (Papal committees), tribunals, and offices. Chief of these for American purposes are the archives of the Congregation of the Propaganda, archives not ordinarily open to historical investigators, but upon which Mr. Fish has reported so fully that it occupies nearly a third of his book. Other ecclesiastical collections are those of the monastic orders, colleges, and churches, and of the religious establishments maintained in Rome by foreign powers. The book also surveys the materials for American history preserved in the Roman archives of the Italian government and the public libraries of the city. Some of the great private libraries were also open to Professor Fish; and he reports on the archives of the foreign embassies in Rome. Next the book reports on the rich archives of Naples, Venice, Turin, and Florence, where are still preserved the documents of the Kingdom of the Two Sicilies, the Republic of Venice, the Kingdom of Sardinia, and the Grand Duchy of Tuscany.

Nearly as far advanced toward publication is the "Inventory of unpublished material for American religious history in Protestant Church archives and other repositories," prepared, through personal investigations, by Prof. W. H. Allison, formerly of Bryn Mawr College, but now professor of ecclesiastical history in Colgate Theological Seminary. The galley-proofs of this have been passed. It will make a volume of about 275 pages, including a full index. The archives of the governing bodies of the various Protestant churches and of their missionary societies, and the libraries of their theological seminaries, colleges, and historical societies, are here presented in an alphabetical order of places, with elaborate and accurate lists of their historical contents. It is hoped that the book, prepared in a catholic spirit and with a sympathetic interest in the history of all religious denominations alike, may further not only the preparation of more useful denominational and local histories of the type hitherto current, but also, and still more, the prosecution of broader work relating to the history of American religion in general.

The last annual report noted the completion of Prof. Marion D. Learned's searches directed toward the preparation of a "Guide to the materials for American history in German archives." During the winter and spring he labored upon the composition of his report, and presented it in June. The summer's examination of it developed the belief that it could be made more useful by certain additions, which, however, can not be completed at the time of the present report, owing to Professor Learned's attendance as a delegate at the centenary of the University of Berlin. It is hoped, however, that the end of December may see the manuscript finished and ready for publication.

Since, for reasons explained a year ago, the search upon which it is based was not confined to one central archive, but ranged through all the chief archives of Prussia and the other German states, the arrangement resembles that of Professor Allison's inventory rather than that of most of our European guides. The various archives are presented in an alphabetical order. But in each case, after a general description of the archive, its American contents are listed in the order indicated by the systematic arrangement prevailing in the interior of German archives. Its itemized lists will be useful to three classes of historical investigators: first of all, to those interested in the history of German migration to the United States, but also to those occupied with the history of diplomatic relations between our country and the German states, and to those occupied with the war of the Revolution and the Hessian and other auxiliary German troops. The book is confined to archives in the German Empire; those of German Switzerland and Austria, including Salzburg, are to be treated later.

Early in October the Department received from Prof. Herbert E. Bolton, of Stanford University, the manuscript of his "Guide to the materials for the history of the United States in Mexican archives," on the writing of which he has been engaged ever since the completion of his prolonged researches in Mexican archives. It is a book of approximately the size of those mentioned above, and composed on a plan bearing a general resemblance to theirs. It covers, as previous reports have indicated, not only the general archives of the Federal Government in the City of Mexico, but a great variety of provincial and local archives in northern Mexico, situated in towns which formerly bore the relation of provincial capitals, civil or ecclesiastical, to those parts of the United States formerly dependent on Mexico or New Spain—Texas, New Mexico, Arizona, Colorado, and California.

During the year some progress has been made in Paris toward the completion of Mr. Leland's "Guide to the materials for American history in the archives of Paris," and in London and Baltimore toward the rearrangement of Professor Andrews's British "Guide" into accord with the new classifications at the Public Record Office.

In June Prof. Frederic L. Paxson, of the University of Wisconsin, and Dr. Charles O. Paullin began work in London, gathering the materials for a "Guide to the materials for the history of the United States since 1783 in

London archives." Professor Paxson, who was able to give but three months to the work, returned in September; Dr. Paullin is still at work. Their monthly reports indicate systematic and effective labor. Professor Paxson made an examination, as thorough as time permitted or the nature of a preliminary guide required, of the various series of Foreign Office papers from 1783 to 1837, preserved at the Public Record Office, and of the papers of the Board of Trade and Privy Council. Dr. Paullin has meantime examined the Admiralty and War Office papers, for the same period, the records of the Custom-House, Treasury, Audit Office, Home Office, Prize Courts, and General Post Office, in so far as these relate to the United States. The examination of the manuscript collections in the British Museum for the period since 1783 has been conducted by the two agents jointly. At the conclusion of the year reported upon, Dr. Paullin had begun work upon the Colonial Office papers, which, with the Foreign Office and Admiralty series, constitute the chief mass of American material.

These departmental papers in the Public Record Office are freely open to public examination down to 1837 (to 1850 in the case of War Office papers). Most of the great European governments set a more recent date, and indeed by special permission several American students have had the opportunity to proceed as far as 1848 in the British Foreign Office papers. It has been hoped that our agents might have permission thus to extend their search and listing. The American Ambassador, Mr. Reid, acting under instructions from the Department of State, interested himself actively in supporting their request; but the desired favor could not be obtained in 1910.

In June the Director of the Department visited the archives of the Dominion of Canada at Ottawa and the provincial archives at Toronto and Quebec. His object was, by preliminary inspection, to determine the possibility or difficulties of constructing a "Guide to the materials for United States history in Canadian archives, national, departmental, and provincial." Doubts had arisen out of the rapidity with which new materials had of late been flowing into the Dominion archives from the ministerial departments and elsewhere, but these doubts were resolved by examination, and the way seems open for the preparation of the desired guide. The project has been received with cordial favor by the archivist of the Dominion, Dr. Arthur G. Doughty, C. M. G., and by the minister of agriculture, Hon. Sydney Fisher, of whose department the archives form a part. Hearty good will toward the enterprise was expressed at the time of the Director's visit by the acting governor-general, Mr. Justice Désiré Girouard; the prime minister, Sir Wilfrid Laurier; the secretary of state, Hon. Charles Murphy, and the minister of militia, Sir Frederick Borden. Since then a beginning in the preparation of the proposed guide has been made by Mr. David W. Parker, a Canadian well versed in United States history, and who for the greater part of the last two years has been engaged in the work of the Department in Washington.

From January to July Mr. Parker had been occupied with the continuation and completion of the calendar of papers in Washington archives relating to the Territories, the beginning of which was noted in last year's report. Under the designation Territorial papers, or papers relating to the Territories, as then explained, it is not intended to include all papers relating to all transactions in the Territories of the United States—military papers, Indian papers, and the like—but rather to furnish a calendar of all those papers, scattered through various Departmental and Congressional repositories in Washington, which concern the Territory as a unit, its government and administration, and its relations to the Federal Government. The history of the Territories is the early history of many States, whose historical societies and students are exceptionally eager in the pursuit of early materials. While the necessary materials for the early history of the older States are to be found within their own borders or in London, the newer States naturally look to Washington for their original sources. Scattered, however, as these are, in the present condition of archival organization at the national capital, the search for them is always difficult, expensive, and uncertain. To have the search made once for all, for all the Territories alike, upon a comprehensive and uniform plan, will provide the active Western historical inquirers with a manual guide which, it is deemed certain, will be of great value.

Having in the preceding year covered by his searches the masses of Territorial material in the Bureau of Rolls and Library and the Bureau of Indexes and Archives in the Department of State, Mr. Parker in the present year devoted himself to the Territorial papers in the Division of Manuscripts at the Library of Congress, to the files of the Senate and House of Representatives, and to the archives of the Treasury Department, Post Office Department, Land Office, and Indian Office. The archives of the War Department are, it is well known, rigidly closed against historical investigators. Some of the other offices mentioned, though abounding in manuscript materials for the history of certain events which occurred in Territorial areas, contained little of that material for the constitutional, political, and administrative history of the Territory as a whole, which was the main subject-matter of the proposed volume. In the case of highly important papers some latitude was allowed beyond the limits which the strictest interpretation of that design would have imposed, but in general the limitation was maintained, for preservation of unity and for avoidance of undue size in the book. Neither was it deemed desirable to include papers of later date than 1873, the year in which the administration of the Territories was assigned to the Department of the Interior.

Of the archives searched in the present year, the House files and Senate files proved to be much the most rich in valuable materials for the purpose. Both indeed are almost virgin soil to the historical investigator. No full account of them could be given in either edition of Van Tyne and Leland's

"Guide to the archives of the Government in Washington." In the case of the Senate files, special authorization was required, and was obtained through a resolution of the Senate, opening this valuable and well-arranged collection of papers to historical investigation for practically the first time. The files of the two houses, though fragmentary in the earlier years, contain manuscript memorials, petitions, and reports in great profusion, as well as bills which, though printed, have from their rarity the status of manuscript. The portion relating to the Territories made a large and important addition to Mr. Parker's set of slips. His manuscript has been turned over by him to the Department and is now nearly ready for the press.

TEXTUAL PUBLICATION OF DOCUMENTS.

During the period from October to March Dr. Burnett was absent from Washington in a northward tour, the object of which was to make the last gleanings of material in that direction for his "Letters of Delegates to the Continental Congress relating to its Transactions." Boston, Hartford, Albany, New York, Newark, Trenton, Princeton, Philadelphia, and Haverford were successively visited, and considerable masses of additional material secured. With few exceptions, the copies of these letters were collated with the originals by Dr. Burnett in person, and exceptional pains taken to secure accuracy of text. During the summer further searches were made at Richmond and among the Lee papers at the University of Virginia. By the kindness of members of the Adams family, the Director was permitted to examine the papers of John Adams. This examination, conducted with the kind assistance of Mr. Worthington C. Ford, added a number of interesting letters to the store now accumulated. With the exception of the material from the library of the South Carolina Historical Society, a body of copies now nearly completed, all the letters and parts of letters to be printed are now in hand. The work of arrangement, comparison, and elimination has been carried nearly to a completion, and other editorial work has been considerably advanced.

Miss Davenport in the first half of the year carried down to 1667 the preparation of her introductions and annotations to the treaties between foreign powers having a bearing on American history. Early in July she sailed for London, where, in the British Museum, she has been revising her material for the sixteenth century, discovering new articles, and continuing her work in other ways.

The "American proceedings and debates in Parliament" has during the year advanced by several stages. Mr. Stock has completed to 1766 his list of items in the Journals of the British House of Commons. A considerable amount of the material so listed has been copied. For the period after 1750, when the American material comes in larger quantities, printer's copy can be more conveniently prepared by cutting up a partial set of the printed Journals, which, along with an unbound set of the Journals of the House of Lords,

the Department possesses. Miss Elizabeth Donnan has worked through three volumes of the Lords' Journals, Mr. B. B. Kendrick through the entire series of those of the Irish House of Commons. In respect to the debates, Professor Manning, at various times up to August, continued his search in volumes professedly devoted to debates and in others in which a certain number of them are casually to be found, and of late especially in the eighteenth century magazines. In London, Miss Mary T. Martin, assisted by Miss Salisbury, has made a beginning of furnishing from Egerton MSS. 215–263 at the British Museum correct texts of the reports of American debates written down privately by Sir Henry Cavendish, M. P. for Lostwithiel in the "Unreported Parliament" of 1768–1774. The important part which American affairs played in that Parliament, and the general exclusion of reporters from it, give a high place as an American historical source to Cavendish's careful reports. A minor part of them was once printed, with a quite inaccurate text; for the most part they remain in manuscript, and to a certain extent in shorthand.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the American Historical Review has been carried on in the office of the Department and by its staff. Mr. Leland has prepared the annual summary of American historical progress appearing in the Jahresberichte der Geschichtswissenschaft and a similar biennial survey for the Revue Historique. In Paris he has supervised the making of the calendar of papers in the French archives relating to the history of the Mississippi Valley described in the last report, and undertaken by an associated group of historical organizations in the United States.

As in previous years, searches and copies have been made by the Department, or under its supervision, for organizations such as the Wisconsin State Historical Society, and for many individuals. Letters of inquiry as to historical papers in Washington and other matters have been answered with great freedom. The Director has, as a matter of course, done what he could in small miscellaneous ways to further the interests in Washington of the American Historical Association and of American historical scholars. Among such minor services has been the private issue of a pamphlet "List of doctoral dissertations in history in progress, December, 1909," prepared in the office of the Department from materials supplied by persons occupied with the preparation, in graduate schools, of candidates for the doctor's degree in history, and sent out in a small number of copies to such persons.

PLANS FOR 1911.

The work of the Department for 1911 should chiefly consist in the continuance of the pieces of work already in progress.

REPORTS, AIDS, AND GUIDES.

Professor Learned's volume on materials for American history in German archives, Professor Bolton's volume on the materials for United States history in the archives of Mexico, and Mr. Parker's on the Territorial papers in those of Washington being completed in manuscript, and Professor Learned's volume on the materials for American history in German archives substantially so, there seems no reason why the printing and publication of the three, if authorized by the Institution, should not be accomplished within the year now ending. They will make volumes of, on the average, 300 pages.

Mr. Leland expects to remain in Paris till his work on the archives there is completed. As soon as is practicable after his return, he will prepare his Guide for publication. The same course is expected to be pursued by Dr. Paullin as to the report jointly prepared by him and Professor Paxson.

Prof. Charles M. Andrews, now of Yale University, will spend in England the period from June to November, and hopes to be able during that period to complete the recasting of his voluminous work on the "Materials in the Public Record Office for the history of British America before 1783." That work, completed three years ago, has since that time been held in suspense by the course of the Public Record Office officials in reclassifying large portions of their modern archives, and especially of those emanating from the Colonial Office, the series most important to American history. Whether Professor Andrews can this year complete the recasting of his book made necessary by these thoroughgoing alterations of system at the Public Record Office depends obviously on the question whether the alterations will by next October have been brought measurably near to their termination.

Mr. Parker, if able to continue in the service of the Institution, will have been able by spring to complete his account of the materials for United States history in the Canadian archives. The archives at Ottawa are extensive, but they are in good order, and some of their largest series consist of transcripts from the English and French archives, made from documents the originals of which are in repositories and series already described by Professor Andrews and Mr. Leland. Moreover, the "Canadian Archives Reports," published in an annual series from 1883 to 1906, contain voluminous calendars of these transcripts. Therefore it is possible for Mr. Parker to treat in a summary fashion the various series in the Ottawa archives consisting of transcripts, and to devote his report mainly to what may be termed the indigenous materials. The report ought also to embrace the central archives of the various Canadian provinces. Those of Ontario have been difficult of access since the fire in the Parliament buildings in Toronto, but may be available in season for our uses. Those of Nova Scotia have the chief value for

United States history. Those of the civil province of Quebec have some importance, and the volume should doubtless include some account, such as the great courtesy of their custodians may permit (though the collection is not a public one), of the ecclesiastical archives preserved at the palace of the archbishop and Laval University. It is probable that, by arrangement with a gentleman who has fairly complete notes on the archives of the British West Indies, we may complete the volume for British America by including those islands, together with the Bahamas, on whose archives we already by chance have a report, and the Bermudas.

The series of preliminary guides to American materials in European archives, projected eight years ago, is by no means completed, as to issue or even as to planning. The archives of a dozen European countries—Scotland, Ireland, Russia, the Scandinavian countries, the Netherlands, Belgium, Switzerland, Austria-Hungary, Portugal—remain untouched. Yet, most of these being of minor importance, the time may well be said to have arrived for advancing from the first stage of exploitation of foreign archives to the second stage. That stage consists in selecting a particular section of some single European archive and subjecting to more explicit treatment, in the form of a calendar, the American materials which it contains. The section chosen should have the highest claim to consideration on account of the abundance, importance, and freshness of its American papers. So much more has been done to make known the American materials in the English and French archives that I conclude upon selecting for this fuller treatment a portion of the Spanish archives, whose riches are much less familiar and have been much less drawn upon. After consultation with Professor Shepherd, compiler of our "Guide to the materials for the history of the United States in Spanish archives," and with others, it seems to me plain that the most desirable section to attack in the manner described is that body of papers in the Archives of the Indies at Seville entitled "Papers from the Island of Cuba" ("Papeles procedentes de la Isla de Cuba"). It is a collection of about 2,500 bundles (*legajos*), embracing some hundreds of thousands of individual papers, sent from Havana to the Archives of the Indies in 1888. The dates run from the middle of the eighteenth century to the middle of the nineteenth. Because of the administrative position of the captain-general of Cuba, in that period, this deposit contains a vast number of papers from places in the present territory of the United States which were formerly dependent upon Havana—from Florida, Louisiana, and the Old Southwest in general—and not a few from portions of our territory once subordinate to the viceroy of New Spain. The collection as a whole, says Professor Shepherd (Guide, p. 77), is of great value.

Its assortment of English and French originals, of which comparatively few appear elsewhere in translation, and its copious mass of documents in Spanish as well, not only provide the materials for a detailed study of Louisiana and Florida under Spanish rule, but they contribute also in high degree to a correct understanding of the relations between the United States and the dominions of Spain in North America and the West Indies.

Señor Don Pedro Torres Lanzas, chief of the Archives of the Indies, has welcomed the proposed enterprise with most amiable kindness. A well-qualified investigator has been selected in the person of Mr. Roscoe R. Hill, of Columbia University, an accomplished student of Spanish-American history, who has resided four years in Cuba. It is hoped that the expedition may be authorized, and that no administrative obstacles may arise to prevent treatment of this particular *bloc*, though its condition confessedly presents some difficulties.

Provision was made by the trustees ten months ago for the preparation by the Director of a project for an Atlas of the Historical Geography of the United States. Progress has been made with this enterprise, but not such as could have been wished. The Director is not able at the present time to present the scheme with desirable completeness; a year from now it will be possible to do so.

TEXTS.

During 1911 Professor Burnett will proceed with the editing of his Letters of Delegates to the Continental Congress relating to its Transactions; Miss Davenport with that of her volumes of treaties. For the volumes of American Proceedings and Debates in Parliament, it may be expected that the journal matter, English, Scottish, and Irish, will be in whole or in large part prepared for printing, so far as the texts are concerned; that the search for speeches in printed books may be brought measurably near to a conclusion; and that further progress may be made in copying from Cavendish's record of debates.

MISCELLANEOUS OPERATIONS: DEPARTMENT BUILDING.

The Department will no doubt maintain in 1911 activities similar to those described above, under this head, in the report concerning the last twelve months. The main matter to be mentioned in this concluding section of this report is, as in the last two years' reports, the need of an adequate building for the Department. The quarters which we have occupied during the past year are paid for by a rental equal to five-eighths of the interest on a suitable lot and building. Though better and more roomy than what we have had hitherto, they have the disadvantages noted at the beginning of this report—noise, dust, undignified surroundings, and remoteness from the Library of Congress. The last prevents effective organization of the Department, since the staff must be working at great distances one from another and from the Director, and diminishes efficiency by consuming time in transit. A fireproof building, plain but dignified, in the immediate neighborhood of the Library of Congress, is the only satisfactory solution of our problem, for the cogent and permanent reason that most of the materials needed for our work are there, and that we work at more than arm's-length if elsewhere.

DEPARTMENT OF MARINE BIOLOGY.*

ALFRED G. MAYER, DIRECTOR.

The single object of the Tortugas Laboratory is to develop the new field of the intensive study of the life of the tropical ocean. No research which has yet been published or is in process of publication from Tortugas could have been performed in any laboratory in the temperate regions, and this will be the fixed policy of the Institution, for its aim is to supplement and extend, not to rival, the effective efforts in research which are being exerted by other laboratories. To so conduct the station as to lead to an actual increase in the output and an improvement in the quality of research is by no means so simple a matter as it might appear, and each year some good worker is advised to go to Woods Hole or some other laboratory to conduct a research for the prosecution of which other places afford advantages equal to or better than those of Tortugas.

The laboratory has constantly aimed to discover the most able students and to urge them to conduct researches under its auspices, and it is flattering to see that the interest now aroused among our active investigators has become so great that this year the laboratory found itself too small to afford room for several competent students of marine life who applied for its tables.

Each year the equipment of the laboratory has been improved, and now it is evident that its capacity must be enlarged so that it may afford the best possible facilities for at least 15 students each summer. With this in view a new building designed to serve as a shed for the shipways and for sleeping quarters for the sailors was constructed. This would have permitted us to convert the old sailors' quarters into a laboratory room, but unfortunately the hurricane of October 17, 1910, destroyed this old building, thus delaying the perfecting of our plans. The new building, however, remains intact and will be occupied.

This necessity for enlargement opens before us the problem of the future development of the station in order that it may maintain an active and increasingly efficient leadership in the development of research in science. We must constantly bear the fact in mind that no laboratory in so unprotected a situation as that of Tortugas can profitably be maintained open during the winter months, when an almost constant trade-wind gale renders it impossible to collect upon the reefs. During the early years of his experience as an explorer of tropical seas Alexander Agassiz's reports are all prefaced with complaints that his expeditions labored under great disad-

* Situated at Tortugas, Florida. Grant No. 604. $14,570 for investigations and maintenance during 1910. (For previous reports see Year Books Nos. 3–8.)

vantages owing to the rough weather of the winter months. Finally he learned that one must go to the tropical ocean in that period of calms extending from spring to early autumn, or during the months which follow the trade-wind season of the winter and precede the hurricanes of the autumn. Moreover, in winter the tropical ocean is barren of larval forms, whereas in the spring a great awakening comes and numbers of animals cast forth their eggs and the young form vast swarms drifting over the calm surface of the warming sea.

Not only do we find an almost constant trade-wind gale and few marine animals in winter, but at this season it is most difficult for college professors to leave their duties for a period long enough to conduct a successful research. Owing to bad weather more than twice as much time must be given to a research in winter as in summer, for in winter one's work is certain to be seriously hindered by bad weather, whereas in summer the long calms will permit of almost constant study of the sea.

It would seem desirable, therefore, to settle upon the policy of maintaining the laboratory in fully active operation only during the spring and summer and correspondingly so to increase its efficiency that the work of its short season will prove as productive as possible.

Very rarely a research leads to the necessity for visiting the tropics in winter, and these special cases can be cared for by the laboratory in accordance with their special requirements, for the new yacht which we hope soon to launch will provide excellent winter quarters for such studies.

For example, it will be necessary for Professor Tennent to study the development of certain echinoderms which breed only in winter, and the researches of Professors Treadwell and Vaughan will certainly lead to winter work. In all these cases it will be well to select some protected harbor, such as Miami, Florida, Nassau, New Providence, or Montego Bay, Jamaica, where one is relatively sheltered from the trade wind. Often researches commenced in the tropics must be supplemented by studies in colder waters; for example, the Director's studies of North American Ctenophoræ will oblige him to visit Newfoundland in the autumn of this year. Thus the work of the laboratory may at times be profitably extended to regions other than the Tortugas.

A progressive change is coming over conditions of research in marine biology, and with it the Tortugas Laboratory must keep pace. Only a few years ago a short period of observation sufficed for the preparation of a good research, but to-day the simpler problems have nearly all been solved, and study to be productive must be more prolonged. It is therefore most important that the laboratory afford facilities for long and elaborate studies such as we may hope will lead to the discovery of fundamental laws. Accordingly, Dr. T. Wayland Vaughan is studying the complex phenomena of the growth and formation of coral reefs, and many years must elapse

before his work can be published. Professor Tower has made a beginning of a long series of observations upon evolution and heredity in beetles at Tortugas. Professor Treadwell hopes to devote years to the study of the morphology, habits, and reactions of marine worms. Other students have been spending successive seasons upon the study of the physiology and chemistry of animal movements and reactions, and it is hoped that these long-continued efforts may lead at least in some cases to important discoveries.

Most important of all, a spirit of tranquillity, simplicity, and ardent devotion to research must be maintained, and for this the Tortugas, with its rare isolation, rich fauna, and perfect healthfulness, affords a unique situation.

As more time must now be devoted to elaborate experimentation and observation than formerly, so does it become correspondingly more necessary that everything be planned to economize and prolong the time devoted to effective study. In order to work continuously we must remain on land, and it is believed that the successful marine expeditions of the future will land parties of students at salient points, where they can establish temporary laboratories; and the vessels will merely serve as a means of facilitating the work of those whose duty it will be to collect for the investigators. We may dispense with the huge, expensive steamer and achieve far more comprehensive and authoritative results by using a number of small fast launches, thus greatly reducing the cost of a marine expedition, increasing the staff of its investigators, and correspondingly enhancing its efficiency. It is hoped that in years to come the Department may be able to conduct such an expedition to the Tropical Pacific.

The United States Navy has practically abandoned Fort Jefferson, and this obliges the laboratory to provide a fast, seaworthy launch which will suffice to make the journey to and fro between Key West and Tortugas in any ordinary weather. The *Physalia* is too slow for this transportation service and is seriously delayed by even moderate head-winds, so that it is often necessary to wait for days at a time before venturing to go to Key West. A new launch 70 feet long, of 100 horsepower, would not only obviate this annoying difficulty of transportation, but would greatly increase the efficiency of the fleet by enlarging the collecting radius and enabling the use of the dredge at greater depths; the additional expense of maintaining such a vessel would be largely offset by a saving in the cost of transportation of freight between Key West and the laboratory.

The vessels and laboratory were uninjured by the hurricane of October 1909, which did much damage at Key West, but the laboratory was seriously damaged by the hurricane of October 17, 1910, although no apparatus was lost, parts of the roof were blown off, and the wind-mills and sailors' dwelling were destroyed. The dock-houses were also seriously damaged, but the dock remained uninjured.

The masts of the *Physalia* had been strained in the gales of 1907 and 1908, and it was found necessary to renew them, and they were replaced by lighter spars, thus giving a greater stability to the vessel. Other extensive repairs were also made upon the yacht, and this season found her to be in better sea-trim than ever before.

The following is a list of the twelve investigators who studied at the Tortugas Laboratory during the season, and the object and duration of their visits:

Dr. L. R. Cary, Princeton University. Development and regeneration of Actinians. June 1 to 29.
E. Newton Harvey, Columbia University. Membrane formation and permeability of eggs. June 15 to 20.
Prof. Dr. E. Jörgensen, Bergen University, Norway. Peridinea. May 16 to June 9.
Prof. S. O. Mast, Goucher College, Baltimore. Reactions of turbellaria to light. June 20 to July 20.
Dr. J. F. McClendon, Cornell Medical College. Effects of fertilization in increasing the permeability of eggs to ions. May 5 to June 30.
Prof. Henry S. Pratt, Haverford College. Trematodes. June 15 to 29.
Dr. Frank A. Stromsten, Iowa University. Lymphatic system of turtles. June 1 to 29.
Prof. David H. Tennent, Bryn Mawr College. Alteration of dominance in hybrid echinoderms. June 15 to July 12.
Prof. W. L. Tower, Chicago University, and his assistant, Mr. R. K. Nabours. Variation and heredity in beetles. May 12 to 13; July 13 to 20.
Prof. A. L. Treadwell, Vassar College. Marine annelids. June 15 to July 6.
Dr. T. Wayland Vaughan, U. S. Geological Survey. Biology of the coral reefs. May 16 to June 13.
Prof. John B. Watson, Johns Hopkins University. Reactions of nesting sea-gulls. May 2 to June 21.

In addition to the above, Dr. William H. Longley, of Yale University, was collector, and Mr. K. Morita, of Japan, artist for the laboratory.

Nine of the investigators returned this year to continue work begun in previous years; and of the three new students two expect to return in 1911. It is the object of the laboratory to encourage elaborate, intensive, and accurate studies which can not usually be completed in one season's work; hence the large number of former investigators who returned this season.

No tropical diseases developed among those connected with the laboratory, but one investigator was stricken with acute appendicitis and was taken to Key West on July 6, where he remained until July 20, under the kind and efficient care of Dr. E. K. Sprague of the U. S. Marine Hospital. Commodore William H. Beehler, U. S. Navy, our constant friend of many years, was also so kind as to throw his house open to the care of the patient, and it is due to the generous interest in his welfare upon the part of Commodore Beehler and Dr. Sprague that he recovered sufficiently to be taken to New York, there to be operated upon on July 27. This unfortunate illness caused us to shorten the season by at least a week; but excepting for the studies of the Director it did not interfere seriously with the researches of the investigators who remained at Tortugas during the time the *Physalia* and her patient were in Key West.

Among the more important results of the season's work, Dr. L. R. Cary succeeded in rearing Hensen's larva of Zoanthinæ until it passed into the *edwardsia* stage with 8 tentacles. He also began a series of growth records and regeneration experiments upon *Alcyonaria* and carried on a study of artificial parthenogenesis in *Palythoa,* and of the early stages of development of *Fissurella* to the free-swimming *veliger* stage.

Mr. E. Newton Harvey finds that dilute solutions of chloroform which are too weak to produce cytolysis will increase the permeability of eggs to NaOH. After being fertilized the egg is more permeable to NaOH than it was before fertilization, and this despite the fact that after fertilization it is surrounded by a fertilization-membrane. Mr. Harvey also studied the phenomena of cytolysis in eggs and comes to conclusions which accord with those of Hamburger and of Koeppe.

Professor Dr. E. Jörgensen, of Bergen, Norway, studied the Peridiniea of the Tortugas.

Prof. S. O. Mast found that the eyes of *Turbellaria* serve to direct these animals in their reactions to light. Without their eyes they do not orient themselves in respect to the direction of a source of light, although they remain sensitive to light, for they become more active when the intensity of light is suddenly increased. Their rate of locomotion is dependent upon the amount of light energy received, not upon a mere change in intensity. Newly regenerated tissue is more sensitive to light than old tissue. The animals can distinguish between the stimulus due to a decrease of intensity and that due to an increase in intensity of light.

Dr. J. F. McClendon discovered that echinoderm eggs become more permeable to electrolytes after fertilization or parthenogenesis than they were before the commencement of maturation. The electric conductivity of eggs increases after they have been fertilized or stimulated by acid to develop. It is suggested that development is caused by increase in permeability to anions, allowing the OH ions of the sea-water to enter the egg and accelerate oxidation. McClendon also found that the freezing-point of the sea-water at Tortugas is —2.06° F. and at Boca Grande Channel —2.11° F. Thus the Tortugas water is practically isotonic with 0.6 molecular NaCl, 0.62 molecular KCl, molecular $MgSO_4$ or cane sugar, and less than 0.5 molecular $CaCl_2$ or $MgCl_2$. The lowering of the freezing-point of Tortugas water as compared with that of other laboratories is as follows: Roscoff, —2.12°; Tortugas, —2.06°; Pacific Grove, —1.90°; Woods Hole, —1.82° to —1.85°.

In this connection it is interesting to present the results of an analysis of Tortugas sea-water made under the direction of Prof. Frank W. Clarke, of the U. S. Geological Survey. His report follows:

UNITED STATES GEOLOGICAL SURVEY,
Division of Physical and Chemical Research.

[Report of Analysis No. 2463. Material received from A. G. Mayer. Water from 2 miles off Loggerheap Key, Tortugas Islands, Gulf of Mexico.]

	Grams per 1000 c.c. water.	Percentage of total solids.	Dittmar, average 77 samples sea-water.
Calcium (Ca)	0.4420	1.22	1.197
Magnesium (Mg)	1.3054	3.59	3.725
Potassium (K)	0.4000	1.10	1.106
Sodium (Na)	11.1957	30.80	30.593
Chlorine (Cl)	20.0762	55.24	55.292
Bromine (Br)	0.0644	0.17	0.188
Sulphur radicle (SO_4)	2.7422	7.54	7.692
Carbonic radicle (CO_3)	0.1257	0.34	0.207
	36.3516	100.00	100.000
Sp. g. at 25° C. compared with water at 4° C			1.02434

Examined by Geo. Steiger and reported June 23, 1910.
F. W. CLARKE, *Chief Chemist.*

Prof. Henry S. Pratt announces his discovery at Tortugas of the only trematode known to have a complete intestinal tract.

Dr. Frank A. Stromsten collected a large number of embryos of the loggerhead turtle and injected the blood-vessels or the lymphatics with india-ink. He believes that the lymphatic system of turtles is constituted largely by the formation of mesenchymal spaces and their subsequent fusion into larger channels. He believes that the lymph-spaces are not connected with the blood-system.

Prof. David H. Tennent repeated and verified his discovery of a method for the control of dominance in hybrid echinoderms by a change in concentration of OH ions in the sea-water. He thus furnishes proof of the possibility of controlling the appearance of certain characters by a change in environment. He gathered abundant material for the much-desired study of the cytological aspects of this important question. The great care which he displayed and the many precautions he took to insure against contamination of the sea-water by sperm, etc., cause me to believe that his results may already be accepted as proven.

Prof. W. L. Tower is continuing his studies with more hope of ultimate success than ever before, but prefers at present not to report on his work.

Prof. A. L. Treadwell continued his studies of the Annelids, especially the Eunicidæ of Tortugas, and a number of colored drawings to illustrate his purposed monograph were made by Mr. Morita. He found that the Atlantic palolo swarmed on the mornings of June 29 and 30, and the moon's last quarter fell on June 29, 1910. Unfortunately a severe illness interrupted his research, but it is confidently hoped that he may be able to resume his interesting studies in 1911.

Dr. T. Wayland Vaughan continued his studies of the œcology of coral-reefs and the conditions affecting the growth and associations of corals. He

is rearing coral polyps from the planula, and has 203 coral heads, composed of 18 species, under observation to determine their rate of growth. His three years' study of the growth-rate of reef corals has already led to the only authoritative conclusions upon this interesting subject, but he intends to devote many more years to the study of this and allied problems of the life of corals before publishing his final results. He presents in connection with this report a summary of his results to date, and this should be read by all who desire information upon this complex subject.

Prof. John B. Watson resumed his studies of the noddies and sooty terns on Bird Key, Tortugas. He caused the birds to be taken from their nests and carried to Mobile, Galveston, New York, and off Barnegat, New Jersey, but none of these birds returned to their nests on Bird Key. His experiments, however, suggested that individual isolation of the birds might prove more favorable for the experiment, and it will be remembered that in his previous trial the birds returned to Bird Key from Cape Hatteras. This year 2 noddies out of three returned to Bird Key from a distance of 460 miles out in the Gulf of Mexico, where no sight of land and no ocean-current could have guided them in their flight.

Alfred G. Mayer confirmed the observation that the effects of ionic sodium, potassium, magnesium, calcium, hydrogen, and ammonium upon the neuro-muscular movements of marine invertebrates are in each case the exact opposite of their effect upon cilia. This enables one to understand why it is that the cilia of the lobes of veligers, preoral ring of trochophores, or combs of ctenophores are active only when the muscles are relaxed and stop the instant the muscles contract.

The following papers based upon work performed at Tortugas, or upon collections gathered there, have been published during the year:

Henri Coutière: The snapping shrimps (Alpheidæ) of the Dry Tortugas, Florida. In Proc. U. S. National Museum, Washington, vol. 37, pp. 485–487. January, 1910.

E. Newton Harvey: Membrane formation and pigment migration in sea-urchin eggs as bearing on the problem of artificial parthenogenesis. In Science, vol. 30, pp. 694, 696, 1909.

Alfred G. Mayer:

Medusæ of the world. 3 volumes, 735 pp., 76 plates, 428 text figures. Publication No. 109, Carnegie Institution of Washington. 1910.

The converse relation between ciliary and neuro-muscular movements. In Proc. Society for Experimental Biology and Medicine, New York, 1909, No. 7, pp. 19–20.

The research work of the Tortugas Laboratory. In Popular Science Monthly, April, 1910, pp. 397-411; photographs.

Alexander Agassiz, 1835–1910. In Popular Science Monthly, 30 pp., 3 figs. Oct., 1910.

J. F. McClendon: Electrolytic experiments, showing increase of permeability of eggs to ions at the beginning of development. In Science, New York, vol. 32, pp. 122–124. July, 1910.

Henry A. Pilsbury: Stomatolepas, a barnacle commensal in the throat of the loggerhead turtle. In American Naturalist, vol. 44, pp. 304-306, 1 figure. 1910.

Charles R. Stockard: The influence of regenerating tissue on the animal body. In Archiv für Entwick.-Mech. der Organismen, Bd. 29, Heft 1, pp. 24–32, 3 figs.

David H. Tennent: The dominance of maternal or of paternal characters in echinoderm hybrids. In Archiv für Entwick.-Mech. der Organismen, Bd. 29, Heft 1, pp. 1–14, 2 figs.

In addition to the above, Messrs. Cowles, Hargitt, Hartmeyer, Harvey, Hooker, Linton, Mast, Mayer, McClendon, Pratt, Stockard, Stromsten, Tennent, and Vaughan have contributed articles which will appear in publications 132 and 133 of the Carnegie Institution of Washington.

On behalf of the laboratory it gives me pleasure to express our gratitude to Commodore William H. Beehler, U. S. Navy, commandant of the naval station at Key West, whose kind and constant interest has been displayed toward the laboratory and all connected with it upon every possible occasion, and in default of whose friendship we could not have adequately maintained the station.

We are also deeply indebted to Dr. E. K. Sprague, director of the Marine Hospital at Key West, whose efficient and kindly care secured the recovery of one of the investigators from a serious illness.

During the season President Woodward, of the Institution, paid an all too brief visit to the laboratory, and it is the hope of the Director and his associates that in coming years such visits may be both frequent and more prolonged.

On July 28, 1910, the yacht *Physalia* and her launches were safely laid up in the Miami River, Florida, where they will remain until after the hurricane season.

The reports of the investigators who studied at the laboratory during the summer of 1910 are herewith presented.

PRELIMINARY REPORTS OF RESEARCHES, SEASON OF 1910.

Report of Researches upon Actinians, by L. R. Cary, Princeton University.

REARING OF ZOANTHELLA AND ZOANTHINA (LARVÆ OF SEMPER AND OF HENSEN).

Two species of the former genus and one of the latter were found in abundance in the eddies at the borders of the Gulf Stream south of Tortugas. In attempting to rear these forms both the method of changing the water in the aquaria twice daily and that of keeping them in a jar with a culture of diatoms were used. The first-mentioned method was the more successful.

The Zoanthinæ (Hensen's larvæ) alone underwent the transformation from the free-swimming larvæ to an apparently normal actinian with eight tentacles. When the transformation was to take place the circular band of large cilia was resorbed, the larvæ became inactive, and settled to the bottom of the jar, becoming attached by the aboral end, the one formerly anterior in locomotion.

After their attachment the appearance of the tentacles took place in the following order: First a single one made its appearance, then one opposite to it (180° away), and then one on each side half-way between the previous pair. This stage with four tentacles lasted for two to three days.

The next lot of tentacles, four in number, made their appearance simultaneously, one arising between each two of those already present. None of

the young actinians went beyond this "Edwardsia" stage, although some of them remained alive for more than two weeks.

In the diatom jars several of the larvæ became attached by the oral end, which on the formation of the tentacles became very much broadened. These individuals also remained in the eight-tentacle stage for several weeks; they were fixed at the time of leaving the laboratory.

RATE OF GROWTH AND REGENERATION IN ALCYONARIANS.

Several species of alcyonarians were studied to determine their rates of growth and powers of regeneration under normal conditions. Isolated individuals, that could be identified at any time on the reefs, were chosen, so that all the conditions of their environment would be normal. Measurements of many colonies were made, both those with only a few polyps and others at least a year old. The location of all these colonies was charted so that they can be kept under observation during another season. In the regeneration experiments all of the operations were extensive. The colonies were charted in the same manner as for the growth records. When last examined, some two weeks after the operations, the amount of separation was unexpectedly large.

EMBRYOLOGY OF PALYTHOA.

The eggs of a *Zoanthid* actinian (*Palythoa mammilosa*) were obtained in abundance from colonies incrusting the shallow reefs about Tortugas. There were no ripe male colonies to be found, but by chemical means artificial parthenogenesis was brought about. In no case did the segmentation result in the formation of more than an irregular planula.

Only a small proportion of the eggs obtained could be stimulated to develop by chemical means, and these invariably came from colonies that on the reef could be recognized by their dark-brown color. This fact, as well as the absence of ripe spermatozoa, seems to indicate that the breeding-season of *Palythoa* is later than the first of July.

EMBRYOLOGY OF FISSURELLA.

A few ripe individuals of *Fissurella* were obtained, the eggs artificially fertilized, and carried through until free-swimming embryos were obtained. On centrifuging these eggs a very striking color separation of substances was obtained, but owing to the fact that so few eggs were available this phase of the work was not carried far enough so that no definite results were obtained.

PEDAL LACERATION IN AIPTASIA.

Material was collected for the study of the processes of the readjustment of tissues in the formation of small individuals by "pedal laceration" in this species. The young given off in the normal manner were preserved, and also, for comparison, those resulting from cutting off small fragments from the outstretched bases of adult individuals. This material was secured to supplement some already collected at Beaufort, North Carolina, and at the Bermuda Biological Station.

Report upon Tortugas Trematodes, by Henry S. Pratt, of Haverford College.

I revisited the Tortugas Laboratory this year for the purpose of making further collections of trematodes from the fishes of the region, in order that the collections of last year might be supplemented and the morphological studies already begun completed. I wished also to study again the live worms of several species of unusual interest and importance of which I have preserved material, trematodes being so extremely contractile that it is often necessary to study them alive in order to determine accurately the arrangement of the organs.

One of the most interesting worms obtained last year was a monogenetic trematode belonging to the genus Monocotyle, which lives on the gills of the whip-ray (*Myliobatis freminvillei*). This trematode differs from other similar worms in several important structural details, *e. g.*, the union of the intestinal trunks at their posterior ends and the presence of a rectum-like cœcum which extends straight back from the point of juncture of the paired intestines to the extreme hinder end of the body. In two of the individuals examined this cœcum opens to the outside through a median dorsal pore which has the exact appearance and position of an anus, although in all the other individuals no such opening was seen. These unusual features made it important to reexamine the animal in order to determine, if possible, to what extent they have phylogenetic significance. A whip-ray was fortunately obtained and a large number of the worms in question were collected.

Other worms which it was important to reexamine were several species belonging to the subfamily Allocreadinæ, which occur in the gray snapper, the grunts, the angel-fish, and the groupers. The worms of this subfamily have excited a good deal of interest recently among helminthologists, and attempts, not altogether successful, have been made to monographize them. The existence of six or eight new species in the Gulf of Mexico makes the Tortugas Laboratory a particularly favorable locality in which to study the subfamily.

Besides these worms, the study of which was the principal object of the visit, I also collected about twenty species of trematodes belonging to other groups.

Report on Annelids, by A. L. Treadwell, Vassar College.

The work at the Tortugas was a continuation of that begun in 1909, on various problems of annelid morphology, including the phenomena of the swarming of the Atlantic palolo. In 1910, this swarming occurred on the mornings of June 29 and 30, the last quarter of the June moon falling on the 29th. There seemed reason to expect further swarms near the time of the first quarter of the July moon, but none occurred at this time.

Pomatostegus stellatus larvæ of the third day settle to the bottom and begin to secrete their calcareous shells. In 1909 a number of these were collected on tiles and placed in the moat at Fort Jefferson, to determine the rate of annual growth. These did not live, and the experiment was repeated in 1910. To determine if the larvæ orient themselves with reference to light rays, they were allowed to settle on glass plates in a dish illuminated from only one side. In their first position of fixation and in the direction of subsequent growth of the shell, for at least the first three weeks there was absolutely no indication of light orientation.

It is proposed to prepare a systematic study of the annulata of the entire West Indian region, and work has begun on a monograph of the Eunicidæ, a group well represented in this region. The paper is to be illustrated with water-color drawings of the living animals, and a number of these were made this season by Mr. Morita.

Summary of Experiments on the Development of Eggs, by J. F. McClendon.

Eggs of the gulf-weed nudibranch *Scyllæa pelagica* (*edwardsii*) were stratified by centrifugal force, but developed normally except for pigmentation.

In the egg of *Spirobranchus tricornis* the pigment is dissolved in oil, which is in the form of droplets. These drops were separated out by centrifugal force, and tested with Sudan III before and after separation. The immature egg can be fertilized with sperm if put into 50 c.c. sea-water containing 2 drops of M/10 NH_4OH.

The immature egg (germinal vesicle intact) of *Ophiocoma rizii* pushes out a membrane when placed in 50 c.c. sea-water containing 3 c.c. M/10 acetic acid. A few matured when left 12 hours in 50 c.c. sea-water containing 1 drop of M/10 NH_4OH.

The eggs of *Echinaster crassispina* are very large in comparison to those of other echinoderms. During the growth period their specific gravity decreases. The small eggs are heavier than sea-water and the full-grown eggs lighter than sea-water. This change is due to the accumulation of oil in drops throughout the cytoplasm. The oil was separated by centrifugal force and tested with Sudan III before and after separation. Brown pigment granules are distributed throughout the cytoplasm, but may be separated out (precipitated) by centrifugal force. The large germinal vesicle lying adjacent to the surface of the egg is so transparent that there appears to be merely a depression in the opaque cytoplasm where it lies. An electric current was passed through eggs that had been sucked up into capillary tubes and placed under the microscope. Each egg became paler toward the anode and darker toward the cathode. Owing to the opacity of the cytoplasm, the movement of individual granules could not be followed, and it could not be determined whether the pigment was moved by electrical convection directly, or indirectly by the current. With too strong a current the pigment is destroyed. All attempts to ripen the eggs failed.

The unfertilized eggs of *Toxopneustes* (*Lytechinus*) *variegatus* and *Tripneustes* (*Hipponoë*) *esculentus* were made to segment by treatment with sea-water containing ammonia, acetic or carbonic acid, or excess of NaCl (hypertonic). In *Toxopneustes* a membrane (composed of or covered by granules) was pushed out after treatment with carbonic acid, but not in *Tripneustes*. An attempt was made to find the best method by which to produce artificial parthenogenesis in these eggs, and no better could be found than Loeb's method of treatment with acid followed by hypertonic sea-water. The eggs of the two species and of different individuals required different durations of the treatment. By increasing the duration of the treatment the rate of development was increased (approached that of fertilized eggs), but the percentage of larvæ developed decreased, indicating injury to the eggs. For *Toxopneustes* 1.5 to 5 minutes in sea-water carbonated in a Sparklet siphon and 30 to 45 minutes in 100 c.c. sea-water plus 16 c.c 2.5 M NaCl was best. If the eggs have remained long standing, a shorter stay in carbonated sea-water is required than if they are fresh, indi-

cating that one effect of the carbonated sea-water is the removal of the jelly. For *Tripneustes* carbonated sea-water 10 minutes, hypertonic 1 hour, is best.

By Kohlrausch's method, the electric conductivity of the eggs of Toxopneustes was found to increase when they were fertilized or stimulated by acid to develop. This experiment was repeated a great number of times and every possible precaution against error taken. The temperature did not vary one-tenth of a degree, the jelly was washed off of the eggs and they were precipitated in the conductivity vessel to exactly the same level for each reading, and the current used would not stimulate nerve. It was feared that the pushing out of "fertilization" membranes would increase the conductivity. Eggs that had remained so long in sea-water that they could be caused to develop without the pushing out of membranes were chosen in many experiments, yet these showed a marked increase of conductivity on beginning development (too great to be the result of CO_2 formation, though perhaps not so great as in those that pushed out membranes).

At Woods Hole it was found that on passing a strong electric current through an egg the "fertilization" membrane was pushed out toward the cathode, whether it previously lay in contact with the egg or not. Some eggs were found to develop *without* even the *formation* of a "fertilization" membrane. However, some critics may yet object to Kohlrausch's method, since masses of eggs must be used and there remains a little sea-water between the eggs. Therefore fertilized and unfertilized eggs were placed in a molecular solution of sugar and examined under the same cover-glass under the microscope. The fertilized eggs were smaller than the unfertilized eggs, indicating that the salts had passed out of the fertilized eggs, decreasing the internal osmotic pressure and causing plasmolysis. If a gradually increasing electric current be passed through such a preparation, the unfertilized eggs begin to disintegrate sooner than the fertilized eggs. This indicates that there are fewer ions in the fertilized eggs or that the ions are not retarded as much by the membranes. This disintegration commences first at the anode end, indicating that the anions can not pass through. This suggests that development is caused by increase in permeability to anions, allowing the OH ions of the sea-water to enter the egg and accelerate oxidations.

The freezing-point of the sea-water at Tortugas was found to be —2.03° C. and that in Boca Grande channel to be —2.05° C.

Researches Performed at Tortugas, July 1910, by E. Newton Harvey, Columbia University.

PERMEABILITY.

During the summer of 1909, at Tortugas, a study of the mechanism of membrane formation in sea-urchin eggs was begun, in hope of finding out the nature of the process, for there is no doubt of its importance in connection with the starting of development of unfertilized and fertilized eggs.

Reasoning from the close analogy to muscle stimulation, the fact that the starting of development (more specifically membrane formation) is essentially a stimulus reaction, in which the result is dependent on the composition and structure of the part stimulated, independent of the kind of stimulus, it was concluded that the same change must occur in an egg (which leads to its development) as occurs in a muscle and leads to its contraction. This change appears to be an increase in permeability of the bounding surface of the cell to some reaction product or products, whereby the chain of reactions, in

which equilibrium is conditioned by the presence of these products, is again able to proceed. It is well known that stimulation in the case both of a muscle and an egg results in an increased production of CO_2.

The problem this summer (1910) was, therefore, to test the permeability of the egg for some one substance and to determine the effect of certain substances in changing the permeability of eggs. We do not know whether the acid or alkali added to sea-water to make eggs mature, or to form membranes, or to render them capable of cross-fertilization, brings about its result by entering the eggs or whether the effect is a purely surface one. The same statement applies to the action of ions on muscle and nerve tissue and cilia.

I have studied the penetration of NaOH into eggs and the method employed is the use of neutral red as an indicator within the cell. This dye is red in neutral and acid solutions and yellow in alkaline solutions.

In echinoderm eggs (*Toxopneustes, Hipponoë,* and *Holothuria*) neutral red is taken up (combined?) by definite granules which stain red. They are present in the fertilized as well as the unfertilized eggs and are characterized by their high specific gravity, for they pass to the distal pole of the egg in the centrifuge whether first stained and then centrifuged or first centrifuged and then stained. If left in the dye for a long time other granules in the general yolk mass also stain. The rate of staining of fertilized eggs (or eggs with artificial membranes) and unfertilized eggs is very different, however, the former staining much the more rapidly. If the unfertilized eggs are left in the solution long enough, as many and as definite granules stain as in the fertilized. This would appear to indicate a difference in permeability to neutral red between the fertilized and unfertilized eggs, and I can therefore confirm for neutral red what Lyon has recently found for methylene blue.

If eggs stained in neutral red are placed in sea-water to which as much alkali has been added as possible without precipitation (100 c.c. sea-water + 1.3 c.c. N/10 NaOH) they retain their red color for over 3 hours; but if this same solution is saturated with chloroform the alkali passes in almost instantly and turns the neutral red to yellow. The change from red to yellow is independent of the swelling of the egg caused by the chloroform, for the penetration of alkali takes place similarly when swelling is prevented (for a short time) by the addition of cane-sugar to the sea-water. Either the NaOH fails to enter or only enters so slowly that it is neutralized within the egg. Since the number of eggs is very small, compared with the bulk of alkaline solution, and the alkali would continue to diffuse in so long as neutralized, it would require an enormous production of acid on the part of the egg to neutralize the NaOH entering. For this reason the first alternative seems the more probable.

By treating eggs stained in neutral red with stronger and stronger concentrations of NaOH in 0.6 molecular NaCl the alkali penetrates the egg more and more rapidly. If a concentration of NaOH which enters the eggs (*Hipponoë*) in 20 minutes be one-quarter saturated with chloroform, the NaOH enters in 10 minutes. One-quarter saturated chloroform has no visible effect on the eggs even after an hour. The effect of dilute solutions of chloroform which *fail to cytolyze* is to increase the permeability of *Hipponoë* eggs to NaOH. The above statement was found true for ether also. It is obvious that the number of substances whose effect on permeability may be tested in this way is limited, for most of them combine with NaOH.

Thus chloroform, one of the most effective substances for producing artificial membranes, increases the permeability of the egg for alkali. It can be further shown, by comparing the time it takes for the stained eggs, fertilized

and unfertilized, to change from red to yellow, that 5 minutes after fertilization the egg is more permeable to alkali despite the fact that it is surrounded by a fertilization membrane. The same is true if we form the membrane artificially with acetic acid. In the only series of experiments performed, with *Toxopneustes* eggs, between 10 and 15 minutes after fertilization the eggs returned to practically the same condition of permeability as the unfertilized eggs. There appears to be a second increase at the time of first cleavage.

Tennent had discovered in 1909 that the sperm of *Holothuria tuberosa* had a very destructive action when added to the eggs of *Toxopneustes*. A rather thick, close-fitting membrane is formed, which fails to push out, while the egg shrinks irregularly. If the sea-water is now made hyperalkaline (100 c.c. sea-water + 1.2 c.c. N/10 NaOH) the alkali enters stained eggs, turning the neutral red into yellow, and soon the egg swells. This suggests that the sperm of *Holothuria* contains a lysin (Loeb) which enormously increases the permeability of the egg of *Toxopneustes* to alkali and which eventually leads to cytolysis.

Attempts to find a stain which will enter eggs and be changed in color by acids, or an egg occurring at Tortugas and containing a natural pigment affected by acids, have thus far been in vain.

CYTOLYSIS.

The problem of cytolysis, as intimately connected with that of membrane formation, was also studied. The two most important phenomena connected with cytolysis in sea-urchin eggs are: swelling of the egg and decomposition of the visible granules, which appear to fuse to larger and more liquid spheres, with a loss of their natural pigment or of their stain if they have first been placed in a solution of neutral red.

By centrifuging and then cytolysing (with chloroform or saponin), or cytolysing and then centrifuging, it was possible to determine that of the three granular substances present only the yolk and pigment granules break down. The oil is unaffected. Swelling and disintegration of the granules take place simultaneously. It is impossible to say which precedes and which follows. Many eggs (*e. g., Spirobranchus*) contain granules which do not break down on cytolysis, yet the eggs swell, so that it would appear as if the connection of the granules in an egg with cytolysis were purely secondary, and that saponin or chloroform do not combine with them and break them up. This supposition is further supported by the fact that the granules (excepting oil) of sea-urchins' eggs are broken up into *exactly the same products characteristic of cytolysis when the eggs are crushed in sea-water*. This can only mean that the conditions for stability of the granules in the egg are very different from those in sea-water; that there is something in the egg in whose presence the granules are stable, which is not in sea-water, or *vice versa*, and that the egg-surface forms an impenetrable barrier for this substance, in so far as simple diffusion is concerned.

It has since been found that calcium salts are the substance in the presence of which the yolk granules are unstable, and that a mere trace is all that is necessary to cause granular disintegration. If cytolyzed in pure 0.6 molecular NaCl the granules remain intact, although they are changed in some way, for any dye or pigment they may contain passes out of them. The egg nevertheless swells. The cytolysis of the sea-urchin egg would be in all respects like that of the annelid were it not for the calcium of the sea-water. The yolk granules of the annelid egg do not break down in sea-water. The

relation of calcium to cytolysis shows further that it is not present in the egg in the same condition as in sea-water and does not pass into the egg in that condition, but does do so the moment swelling of the egg begins.

The conception of cytolysis to which I have been led is essentially that of Hamburger, Koeppe, and other physiologists. It is certain that during cytolysis there is a progressive change from complete impermeability to complete permeability for most diffusible substances; for it is a change from a definite plasma membrane to no true surface whatsoever if the eggs remain in the solution long enough.

The apparent surface of cytolized eggs is in reality merely the artificial fertilization membrane formed by the cytolytic substance in the first stages of cytolysis. The permeability of the plasma membrane is increased to a certain extent, and under these conditions substances pass out which form an albuminoid membrane. In the next stage the egg-surface becomes permeable to the salts of sea-water when swelling and disintegration of the granules takes place, and at the same time the *egg-surface* loses its continuity. The cause of the swelling is simply the substitution of a surface freely permeable to salts in place of one quite impermeable to them.

In the normal egg the sum of the osmotic pressures of the substances within the egg just counterbalances that of the salts of sea-water. This does not mean that the substances within the egg are the same as those without. The egg is not a mass of proteid saturated with sea-water, but its salt content is different. Suddenly the membrane separating these two phases becomes permeable for the dissolved substances of one phase but not for those of the other. The result is the same as placing the cell in distilled water. It swells until its turgor pressure is balanced by the tension of its artificial membrane.

The slowness with which eggs swell when placed in distilled water, considering the large surface area, points to the view that even water encounters resistance in its exit from and entrance into the egg. In distilled water the egg slowly swells to a certain size, at which point it suddenly swells and a delicate membrane forms. I am inclined to believe that at this point the surface becomes freely permeable to the entrance of water, at the same time losing its continuity, and the whole egg swells (within the artificial membrane which forms) until its internal pressure is compensated by the tension of its membrane.

Preliminary Report on Reactions to Light in Marine Turbellaria, by S. O. Mast, Goucher College, Baltimore.

Four different species of marine turbellaria were used in the experiments on reactions to light, performed at the Tortugas Laboratory, during the latter part of June and the first part of July 1910. The reactions in all of these species are essentially the same. Under favorable conditions they orient and move fairly accurately from the light if there is but a single source. There is, at least in many instances, no indication of preliminary trial in the process of orientation. If light strikes these animals from one side they ordinarily turn directly from the side most highly illuminated. If they are exposed to light from two sources they proceed from a point between these two sources; but the location of this point depends upon the relative intensity of the light which comes from each of the two directions.

The chief object of this work was to ascertain: (1) the function of the eyes in the reaction of the turbellaria to light, and (2) the nature of the stimulus.

(1) Most of the turbellaria have numerous eyes, or eye-spots, two of which are situated near the middle of the anterior end and the rest near the edge of this end extending some distance back. In one of the species studied only two eyes were found, and these were cut out in a number of specimens which had been quieted in an isotonic solution of magnesium sulphate.

Nearly all of these animals recovered and the wounds were healed in two days. They responded to light by becoming active when exposed in strong illumination, but no indication of orientation in any of them was observable until after the eyes had regenerated; and the same results were obtained with specimens of the other three species in which the eyes were removed by cutting off the entire anterior end. This end, in spite of its diminutive size, oriented very soon after the operation, but the remainder, the portion which contained no eyes, showed no indication of orientation in any instance, although to an increase of intensity it responded definitely by becoming more active and sometimes raising the anterior end and swinging it from side to side. These results show clearly that the eyes of the marine turbellaria function in the process of orientation.

(2) As to the nature of the stimulus, we wish to consider only the question: Are the turbellaria stimulated by light owing to an effect produced by virtue of a change of intensity or to some effect produced by virtue of constant or continued intensity, *i. e.*, the absolute amount of energy received at a given time as compared with the amount previously received?

All of the species of marine turbellaria tested, as already stated, become more active when the light intensity is increased. This is true for specimens with the eyes removed as well as for others. But the increase in activity does not take place until some time after the intensity of the light is changed. This seems to indicate that the stimulus which regulates the rate of locomotion is dependent upon the amount of energy received, that is, *constant intensity*, not change of intensity.

With reference to the nature of the stimulus which regulates orientation the evidence is not conclusive, although it indicates that it is due to *change of intensity*.

Planaria with one eye removed, either by gouging it out or by cutting off one side of the anterior end obliquely, turn continuously from the wounded side for some time, evidently owing to the stimulation of the wound, since after this is healed they tend to turn in the opposite direction. After regeneration is nearly complete they orient practically as accurately as normal specimens. But if the light intensity is suddenly increased after the animals are oriented in a given beam of light, without any change in the direction of the rays, they turn sharply from the side containing the regenerated tissue. The fact that the planarians turn in this direction indicates that the regenerated tissue is more sensitive to light than the old tissue; and that it is probable that the orienting stimulus in these animals is due to *change* of intensity—that there is no stimulation resulting in orientation unless the intensity on some part of the body changes. This is usually produced by the shading of one part of the body by another (probably the sensitive part of the eye by the opaque part) owing to the change in the axial position of the organism.

Planaria exposed at the intersection of two beams of light which cross at right angles orient with the anterior end directed from a point between the sources of the two beams. If, after the animals are oriented, the light in one of the beams is intercepted so as to decrease the intensity on one side of the organisms, they usually turn directly toward the side on which the intensity was decreased until they are oriented in the single beam of light. If the light in the second beam is now thrown upon the animals so as to increase

the intensity on one side they turn directly from this side. Consequently if the orienting stimulus is the result of a change of intensity, the animals turn toward the side stimulated when it is due to decrease of intensity, and from this side when it is due to increase of intensity. And if this be true, they must be able to distinguish between the stimulations due to the two different conditions of illumination.

Report upon the Lymphatic System of the Turtle, by Frank A. Stromsten, Iowa University.

During four weeks' stay at the laboratory material for the study of the anatomy and development of the lymphatic system of the loggerhead turtle was collected. About 150 embryos were collected and preserved, and one adult specimen was dissected.

The loggerhead turtle, which at one time was very abundant in the region of the Dry Tortugas, is now becoming rare. During the present season scarcely a score of the females visited the islands to lay their eggs, while many years ago it is said that as many would crawl upon the beach in a single night. At present every nest is robbed of its eggs and nearly every turtle that reaches the shore is captured and killed by "turtlers" and fishermen. The only eggs allowed to develop during the present season in this entire group of islands, as far as is known to the writer, were those obtained and protected by the laboratory. Unless some means is soon taken for their protection, it can be a matter of but a few years until the loggerhead turtle will practically be extinct in the Florida region.

The female turtle usually lays her eggs about midnight, some time between 10 and 2 o'clock. She crawls up the low sandy beach to a desirable spot above the line of high tide and scoops out a hole about 18 inches deep in the loose sand with her hind flippers. In this nest she deposits from 100 to 150 or more eggs. The eggs are spherical in shape and have a diameter of 40 to 45 mm. The tough membranous shell is pinkish-white at first, but as development proceeds it becomes a dead white. The eggs are arranged in a half dozen or more horizontal layers in the nest, and are carefully covered with sand in such a manner as to effectually conceal the exact locality of the nest. The time occupied in laying the eggs is about 30 minutes. During this time it is very easy to capture the turtle, as she is not easily frightened and may be readily approached and turned. She may be left thus lying on her back indefinitely, as she is not able to right herself.

The eggs intended for study were usually removed from the original nest as needed. In certain cases, however, where the nest was too remote or inaccessible, it was carefully moved to the neighborhood of the laboratory. In removing the eggs it is very essential that they are not turned or shaken, else the process of development will stop and the embryo die. For that reason the top of each egg was marked with a soft lead pencil before it had been disturbed from its original position in the nest. After being thus marked the eggs are carefully removed, one by one, without turning or jarring, and replaced in the new nest in as nearly the original condition as possible.

The embryonic material was fixed in most cases in either "chrom-aceto-formaldehyde" or in Bouin's fluid. A complete series of stages from 12 to 30 days of development was obtained. In one complete series the blood-vessels were injected with India-ink. In some of the specimens the lymphatics were also injected. A further consideration of the methods will be given at another time.

The work thus far carried on seems to indicate that the formation of mesenchymal spaces and their subsequent fusion into larger channels play a

more important part in the development of the lymphatic system of turtles than we have hitherto supposed. The present series of investigations is being carried on by using both the injection and wax-reconstruction methods in the hope that by using one method to check the other accurate results may be reached.

Experiments in Echinoderm Hybridization, by David H. Tennent, Bryn Mawr College.

During my stay at Tortugas I repeated and verified my observations of 1909 concerning the control of dominance by a change in the concentration of OH ions in the sea-water.

The cross-fertilizations between *Hipponoë* (*Tripneustes*) and *Toxopneustes* were made in ordinary sea-water with the facility of the previous summer, and (as before) there was a preponderance of *Hipponoë* characters, indicated by fenestrated and by multiple anal arm-rods. An additional evidence of *Hipponoë* influence was shown in the culture of 1910, namely, by the "basket" which is formed by the union of the dorsal and ventral body-skeletons in purely-bred *Hipponoë* plutei. This structure did not appear in the hybrid larvæ of 1909.

The *Hipponoë* characters were not responsive, in the same degree, to the addition of the same amount of acid to the sea-water as in 1909. A further reduction of the OH ion concentration brought results similar to those originally obtained. This is another example of the normal variation in environment which has been the cause of some of the confusion in the recorded observations of the various investigations, made in the same localities but in different years.

The following table summarizes the investigations on the *Toxopneustes* × *Hipponoë* cross. It shows clearly that the effect of the reduction in alkalinity has been to decrease the *Hipponoë* characters and to increase the *Toxopneustes* characters.

Summary of Results of Cross-fertilization. Toxopneustes ♀ × Hipponoë ♂.

[Number of plutei studied in each series, 50.]

Medium.	Age.	Plutei with lattice structure.	Anal arm-rods with lattice structure.	Arms more than 1 rod.	Perfect Hipponoë rods.	Perfect Toxopneustes rods.	Perfect Toxopneustes plutei.	Perfect Hipponoë plutei.	Basket.
	days.								
1. Ordinary sea-water	3	24	32	60	0	8	0	0	25
2. 500 c.c. sea-water + 15 gtts. N/10 acetic	3	4	5	93	0	2	0	0	7
3. Do	4	14	16	81	0	3	0	0	10
4. Do	5	13	15	69	0	16	3	0	12
5. 500 c.c sea-water + 2 c.c. N/10 acetic	2	3	5	51	0	44	6	0	2
6. Do	2	4	6	49	1	45	5	0	1
7. 500 c.c. sea-water + 15 gtts. N/10 HCl	3	20	24	71	0	5	0	0	9
8. Do	4	17	17	79	0	4	0	0	13
9. Do	5	13	16	66	0	18	3	0	8
10. 500 c.c. sea-water + 30 gtts. N/10 HCl	2	6	9	51	0	40	4	0	2
11. Do	2	5	7	49	0	44	2	0	1

These investigations have furnished proof of the possibility of controlling the appearance of certain characters by a change in environment. My observations, together with those of Herbst, show that there is an optimum environment for the occurrence of definite characters. This environment is a complex of factors. Two of the factors are temperature and OH ion concentration.

The chief aim of the work in 1910 was the acquisition of material for a study of nuclear activities in eggs whose potencies had been determined by OH ion concentration. An abundance of material was obtained, but no report can be made until the cytological study is completed.

The Recent Madreporaria of Southern Florida, by Thomas Wayland Vaughan, U. S. Geological Survey.

SURVEY OF THE CORAL FIELDS.

The survey of the coral fields of the Tortugas was continued in 1910 and three additions to the list of the shallow-water madreporarian fauna were made, viz: *Astrangia solitaria,* which grows on calcareous blocks on the reefs off Loggerhead Key; *Cladocora arbuscula,* which is attached to the outer face of the northwest side of the Fort Jefferson moat-wall; and *Acropora palmata,* which was observed by Dr. Mayer in the Five-Foot Channel, off Bush Key reef, in water about 5 feet deep.

Acropora cervicornis and *A. prolifera* covered acres or even square miles of the shallow-water flats around the Tortugas previous to the "Black Water" period of 1879, when they were nearly all killed. For many years subsequent to this general destruction only occasional specimens of them could be found, the principal locality being off the northwest face of Loggerhead Key in water about 20 feet deep. Now, however, they are rapidly reestablishing themselves, and have become fairly common on the flats west of Garden Key off Fort Jefferson, and on the flat north of Bird Key, in water 4 or 5 feet deep. The present tentative list of Tortugas Madreporaria comprises 27 species and forms,* including most of the common reef and flat corals of the Antillean and Floridian regions.

The annual surveys of the piers of the Fort Jefferson dock and of the Fort Jefferson moat were continued. In both localities young corals were discovered and measurements to determine growth-rate initiated. Especially noteworthy among the young corals are single-caliced specimens of *Eusmilia* and small *Mœandra clivosa* on the piers of the dock, and a young *Oculina* in the moat.

The continued observations on the piers of the dock seem to show that strong light is essential for the growth of shallow-water corals, as the piers in the permanently shaded area under the dock are devoid of corals, while they are abundant wherever the light is strong. Skeletal texture and strength of basal attachment are other factors determining habitat. Corals with fragile skeletons, such as *Eusmilia* and *Oculina,* can not live in the region of breakers, while that kind of environment is favorable for massive species, such as *Orbicella annularis* and *Porites astreoides.* Species with narrow bases of attachment, as *Mœandra arcolata,* are necessarily limited to rather quiet water.

The annual examinations of the moat show gradual changes in the biologic associations. Certain algæ, both non-calcareous and the calcareous *Halimeda,* are becoming more abundant, while ramose bryozoa are very prolific. In some instances these organisms are overgrowing the corals, and probably killing them. Evidently here is an opportunity not only to study the adaptability of the corals to moat conditions, but also to observe the struggle for supremacy between different groups of organisms.

Effect of exposure between tides on corals.—Between June 6 and 8 was a period of unusually low tide, accompanied by very calm weather, causing the exposure of the tops of many colonies and in other instances exposing entire

* Variations and forms are treated as species in this report.

colonies for several hours without the usual dashing of water over them through agitation by wind or ocean-swell. Two photographic illustrations of the appearance of one of the reefs off Loggerhead Key are here presented (plate 1, figs. A and B). The corals in the Fort Jefferson moat were also examined to ascertain the effect of the exposure.

The ability to withstand exposure between tides seems to be a function of the porosity of the skeleton. On the reefs the tops of the heads of *Orbicella annularis* were bleached, and at least the superficial soft tissues were killed. In the moat the superficial soft tissues of *Eusmilia, Orbicella annularis, Mœandra areolata, M. clivosa,* and *Manicina* (*"Colpophyllia"*) *gyrosa* were killed, and the same was also the case with some specimens of *Favia fragum,* or all corals with imperforate hard tissues. The amount of regeneration that may take place from living tissue deeply situated in the skeletons can not be ascertained before inspection during the next field season. It should be stated that even these corals may stand atmospheric exposure if kept saturated with sea-water. *Siderastrea radians*, the skeleton of which is slightly perforate and is made more spongy by synapticula, withstands exposure better than corals with imperforate skeletons; while the various species of *Porites* seemed to be not at all affected by an exposure of several hours, their extremely porous skeletons insuring a continuous supply of water through capillarity.

That *Orbicella annularis* heads are often partially killed by exposure is attested by the dead summits of large heads, which are usually submerged, off the western side of Garden Key.

RATE OF GROWTH OF CORALS.

The report for 1909* contains notes on measurements instituted to ascertain the growth rate of corals, and a few comparative measurements made in 1908 and 1909 are given. In 1910 the colonies measured in 1908 and 1909 were remeasured, except in those instances in which the colony had been broken from its attachment or had died, and the series of measurements was greatly increased. It was stated in the 1909 report that the measurements were then not sufficiently accurate. An attempt has been made to remedy this defect by referring the colonies to horizontal and vertical coördinates. Plumb-lines were attached to the instruments to get vertical lines, and the horizontal was determined by an arm perpendicular to the one to which the plumb-line was attached. Nevertheless, as corals are very irregularly shaped objects and grow in various positions, and as it is difficult to measure under water in the ocean, even in quiet weather, only approximate accuracy can be expected. Cementing specimens to tiles and photographing them before planting has been initiated, hoping thus to obtain more accurate results than by measurement alone. It is very desirable to determine both the weight and the volume of the skeleton produced in a known period of time. It will be possible to determine these directly in specimens reared from larvæ; and they can be closely estimated when such growth observations as are now being made become sufficiently numerous.

In the succeeding notes on the present status of the investigation each species is considered separately. In several instances tentative estimates of the age of average-sized adult colonies are given; these estimates, although they seem reliable, must not be considered as facts, and are being checked by numbers of observations. Madreporarian colonies are limited in growth, a fact which brings up for consideration the cause of this limitation. The

* Carnegie Institution of Washington, Year Book No. 8, 1909, pp. 141–142.

hypothetical explanation is offered, that limitation in growth is caused by the natural limit of asexual reproduction of a sexually produced polyp. To state this hypothesis in other words: a sexually produced polyp may bud or divide; each polyp thus asexually produced can give rise to only a limited number of asexual generations, and if sexual reproduction does not intervene the species will become extinct.

Eusmilia knorri.—In 1910 observations or measurements were again made on two colonies, the records for which began in 1908, and one, the record for which began in 1909, all three colonies growing attached to the piers of the Fort Jefferson dock. Although the data are meager, they indicate rapid growth, the increase in the three dimensions varying from 33 per cent to 100 per cent, and the increase in the number of calices from 100 per cent to 200 per cent per annum.

During 1910 the number of records was increased to 14, 10 of them being without measurements and 4 with measurements. Each of two of three specimens first measured in 1910 consisted of a single undivided calice. The next season's field observations may furnish sufficient data to determine the time required for growth from the initial calice to an average-sized mature specimen.

Dichocœnia stokesi.—A single colony of this species, living in the Fort Jefferson moat, is under observation. It is attached to the vertical face of the outer wall, near the southeast exit; it is permanently submerged and through the nearby entrance receives a supply of pure sea-water. The specimen is large: Length in 1909, 363 mm.; in 1910, 368 mm.; an increase in one year of 5 mm., or 1.38 per cent. Breadth in 1909, 297 mm.; in 1910, 315 mm.; an increase of 18 mm. or 6 per cent. The measurement of the thickness in 1909 is not reliable. The growth of this colony was slight, and as it is already large perhaps it has almost reached its growth-limit.

Oculina sp. probably diffusa.—In 1908 records were begun for three colonies attached to the piers of the Fort Jefferson dock; in 1909 records were begun for one additional colony attached to a pier and for two growing in the moat. Three colonies, attached one above another to the same pier of the dock, show the following percentage increase in height: the uppermost, 175 per cent; the median, 75 per cent; the lowest, 33.33 per cent. The uppermost colony has increased in height more than five times as rapidly as the lowest. As the uppermost has the strongest light, this may be the accelerating factor. Another colony on a pier showed an increase in height during the year from 75 to 128 mm., a percentage increase of 70 per cent. Two colonies in the moat showed respectively an increase in height of 41 to 62 mm., or 77 per cent, and 35 to 60 mm., or 86 per cent. The increase of the number of branches in these two colonies was about 100 per cent.

In 1910 a young *Oculina* was discovered beside the two others in the moat, and as it was not seen in 1909 probably represents a year's growth. Its dimensions are as follows: Diameter of basal expansion in horizontal plane, 32 mm.; in vertical plane, 28.5 mm.; one branch projects horizontally 22 mm. from the basal expansion. A large colony on a dock pier is 350 mm. in diameter and 100 mm. tall. The annual growth-rate in height is from 15 to 35 mm., with about 25 mm. as an average. Therefore, a colony may grow to a height of 100 mm. in four years under moderately favorable conditions; the range in the attainment of such a size would probably be from three to seven years.

In 1910 the number of growth records on this species was increased from 6 to 11.

Favia fragum.—In 1909 records were begun on six colonies living in the moat. In 1910, two of these were apparently dead, two showed very little or no growth, while the other two had grown considerably. The death of two colonies and the retardation of growth in two others were probably due to exposure at low tide; and the other two, probably for the same reason, are really not thriving. Evidently this species can not withstand atmospheric exposure so well as species with more porous skeletons. Of the two specimens that had grown, one had increased in length over 100 per cent; the other had increased in breadth 57 per cent. Data obtained in 1908* showed that planulæ attached between May 11 and May 18 had grown by July 22 to calices having a diameter of 3.5 to 5.5 mm., with an average of about 4.5 mm., or they had attained this size at an age between 66 and 73 days. At this rate of growth, at the end of the first year a specimen should be about 20 mm. in diameter. An adult specimen, about 60 mm. in length, is estimated, from the combined data procured to the present time, to attain its size within about three years.

In 1910 the number of growth records was increased to 30, nearly all of the specimens being below the level of the lowest tide, and therefore not subject to exposure between tides.

Mœandra areolata.—Only one growth record is available. It is of a specimen transferred from the piers of the Fort Jefferson dock to the moat and planted near the southeast exit. Its length in 1908 was 40 mm.; in 1909, 54 mm.; in 1910, 80 mm.; an increase of 100 per cent in two years. Its breadth in 1908 was 27 mm.; in 1909, 46 mm.; in 1910, 69 mm.; an increase of 156 per cent in two years. Its height in 1909 was 28 mm.; in 1910, 42 mm.; an increase in height of 50 per cent in one year. It is estimated that this specimen is about four years old; and, as it is almost adult, indicates that the probable age of an adult specimen is from four to five years.

In 1910 the number of records for *M. areolata* was increased to 21.

Mœandra viridis.—The only growth record is of a rather large head living on the reef off Loggerhead Key. Its length in 1909 was 432 mm.; in 1910, 445 mm.; an increase of 13 mm. or 3 per cent. Its breadth in 1909 was 325 mm.; in 1910, 341 mm.; an increase of 16 mm. or 5 per cent. Its height in 1909 was 347 mm.; in 1910, 371 mm.; an increase of 24 mm. or 7 per cent. In actual amount of growth, the increase in size, compared with that of young *Mœandra clivosa* colonies, is slight, suggesting that this colony is approaching its growth limit.

Mœandra clivosa.—Seven colonies, all living in the Fort Jefferson moat, were measured in 1909; one of these had disappeared in 1910, leaving 6 colonies which were again measured. The percentage increase in length and breadth ranged from 14 per cent to 113 per cent, the 113 per cent representing an increase in length from 99 to 211 mm. The increase in thickness for the six specimens was, respectively, 124 per cent, 15 per cent, 48 per cent, 114 per cent, and 76 per cent.

Although information on the initial stages of this species is not yet sufficient, there is some. A young specimen, which is now growing on one of the piers of the Fort Jefferson dock and has diameters of 30 and 40 mm., respectively, probably represents a year's growth, as it was not seen when the pier was examined in 1909. A major diameter of 300 or 400 mm. is common for large specimens. From the data obtained, it is estimated that a colony

* Carnegie Institution of Washington, Year Book No. 7, 1908, p. 135.

under favorable conditions of growth may attain a length of 200 mm. in three years; and with a subsequent annual increase of 50 to 100 mm., a maximum diameter of 300 mm. would represent four to five years; 400 mm., five to seven years; 500 mm., six to nine years. Ten years' growth would produce a large corallum. Should the environment be unfavorable, a colony may increase only slightly in size.

In 1910 the number of records for *M. clivosa* was increased to 16.

Manicina ("Colpophyllia") gyrosa.—Two specimens are being annually measured. One of them was transferred from a pier of the Fort Jefferson dock and planted in the moat near the southeast exit in 1908. A mistake was made in the identification of this coral, while its skeleton was covered by living soft tissue, and in the reports for 1908 and 1909 it is referred to as *Mœandra labyrinthiformis.** Its length in 1908 was 65 mm.; in 1909, 85 mm.; in 1910, 122 mm.; an increase of 88 per cent in two years. Its breadth in 1908 was 65 mm.; in 1909, 85 mm.; in 1910, 112 mm.; an increase of 72 per cent in two years. Its height in 1908 was 20 mm.; in 1910, 32 mm.; an increase of 60 per cent in two years.

The other specimen, which is attached to a pier of the Fort Jefferson dock and is shaded above by an *Oculina* colony, seems to have grown but little. In 1909 it had a maximum diameter of 144 mm. (erroneously given as 154 mm. in the report of 1909); in 1910 diameter in horizontal plane 147 mm.; in vertical plane 132 mm.; thickness 55 mm.

Siderastrea radians.—Seven colonies living in the moat were measured in 1909; of these, in 1910 two were apparently dead; two others had grown but little, while the three others had increased in length and breadth, the range of increase being from 21 to 46 per cent. The largest of these colonies now has a length of 58 mm.; all are therefore small. The growth rate as compared with other species is slow and the colonies appear not to be thriving. Exposure at low tide is probably the principal disadvantageous factor.

In 1910 the number of records was increased to 10; six of the specimens are cemented to tiles planted off the northwest face of the Fort Jefferson moat wall and are permanently below water-level.

Agaricia sp., probably fragilis var.—Previous to 1910 only one colony was measured. It was attached to a pier of the Fort Jefferson dock, but was knocked off between the summer of 1909 and 1910. It was an attached thin plate, and showed between 1908 and 1909 an increase in length from 50 to 69 mm. or 38 per cent; in width from 37 to 54 mm. or 46 per cent.

In 1910, 10 new records were initiated upon this species of *Agaricia.*

Porites clavaria.—Two colonies growing in the moat were measured in 1909 and again in 1910, but the data are not satisfactory. The increase in length and breadth ranged from 54 to 100 per cent; that in height from 10 to 43 per cent. The growth rate under favorable conditions is evidently rapid.

In 1910 the records upon *Porites clavaria* were increased to 8.

Porites furcata.—Thirteen colonies, two attached to piers of the Fort Jefferson dock and eleven living in the moat, were measured in 1909. Of this number, two colonies in the moat had not grown or had been damaged, while the remaining eleven furnished interesting information. As the table embodying the data is long, it will not be inserted here, but remarks on it will be made.

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* Carnegie Institution of Washington, Year Book No. 7, 1908, p. 135; Year Book No. 8, 1909, p. 142.

The specimens on the piers show an increase in length and breadth of as much as 64 and 79 per cent; in height, 41 and 105 per cent. One specimen that in 1908 had one nodule on its surface, in 1910 had seven stocks, each subdivided; thus within two years an incrusting base may develop a clump of branches. The growth-rate varied greatly between the specimens in the moat, seemingly those nearer the exits growing more rapidly than those more distant. The increase in length in one instance reached 210 per cent; in breadth, in the same specimen, 163 per cent; the maximum increase in height was 207 per cent, while in the other more favorably situated colonies, 67, 69, 74, 92, 155, and 168 respectively represent the percentage increase. The branching is as rapid as the general growth; a few nodules of one year may be replaced in the succeeding year by stocks and clusters of branches, rendering recognition of the colony in successive years impossible without marking. Within three or four years a rather large colony may be produced.

In 1910 the number of records for *P. furcata* was increased to 26.

During the field season of 1910 additional colonies living on the reefs off Loggerhead Key, on the piers of the Fort Jefferson dock, and in the moat were measured and records were made. Specimens of corals fastened by Portland cement in 1909 thrived, showing that this material can be used in affixing corals for planting in desirable localities. Eighty-six specimens were cemented to tiles, and after having been photographed and measured were planted on iron stakes off the northwest outer face of the Fort Jefferson moat wall in water ranging from 12 to 18 inches in depth at the lowest tide. Ten other specimens were cemented to tiles and, after having been sketched and measured, were planted in a live-car, intended to withstand hurricanes, off Loggerhead Key.

The number of records by species is as follows:

Number of Growth Records by Species.

Name of species.	No. of records.	Name of species.	No. of records.
Eusmilia knorri	14	Manicina gyrosa	2
Dichocœnia stokesi	1	Siderastrea radiaus	10
Oculina, probably diffusa	11	siderea	4
Astraugia solitaria	4	Agaricia, probably fragilis var	10
Orbicella annularis	11	probably crassa	11
cavernosa	4	Porites clavaria	8
Favia fragum	30	furcata	26
Mæaudra areolata	21	astreoides	12
viridis	1	Too young for identification	7
clivosa	16	Total	203

These 203 records are distributed over 18 species, forms, or variations. Less than 10 records for a species is of course valuable, but as so small a number is not sufficient, an effort will be made to get at least 10 records for each species. This is possible in most instances, for a colony may be divided and each part, after attaching it with cement, can be used for growth experiments. At present there are no serial observations or measurements on 9 species or forms known to live around the Tortugas, but, as material can be obtained of 4 of these 9, the deficiency can be partially remedied during the next season's field work.

Young stages of about half the species have been obtained, permitting the growth to be rather confidently followed from the end of the first year.

Attempts are being made certainly to fill this gap by rearing colonies from the planula stage. These experiments will be subsequently described.

As the records for one or two years clearly show variation in growth-rate for different colonies of the same species, a consideration of the factors accelerating or retarding growth becomes necessary. At present it seems that strong light and pure ocean-water are two accelerating factors, but the data on them are vague. A thorough knowledge, which we do not now possess, of the feeding-habits and the food-supply is essential before these problems can be solved.

The tiles planted on the reefs in 1909, in the hope that young corals would settle on them and furnish material for growth observations, had collected nothing in 1910, but were left undisturbed, hoping for ultimate success.

REARING CORALS FROM PLANULÆ.

Results of previous attempts.—During the field season of 1908 planulæ of *Favia fragum* attached themselves to the bottom of a glass vessel, which was placed in a live-car that broke its moorings during a storm. These planulæ attached themselves between May 11 and 18, 1908, and on July 22, when measured by Dr. Mayer, had attained a size ranging from 3.5 × 4 mm. to 5 mm. in diameter. In 1909, twelve tiles bearing attached young were planted, but in 1910 no trace of living coral could be found on them, all evidently having died.

Experiments in 1910.—In 1910, 50 cultures were made, as follows:

Planula Cultures made in 1910.

Name of species.	No. of cultures made.	No. of tiles to which planulæ attached.	Successful cultures.	No. of planulæ that attached.
			per cent.	
Astrangia solitaria	1	0	0.0	0
Favia fragum	8	3	37.5	16
Agaricia crassa	4	1	25	3
Porites clavaria	20	4	20	29
astreoides	17	13	75	155
Total	50	21		203

The culture technique was considerably improved during this season and will be briefly described. An effort is made to have the planulæ settle on tiles having a central perforation by which they may be fitted over the heads of iron stakes. The tiles have a diameter of 8 inches and are placed in jars, the inside diameter of which is about 8.25 inches and the depth about 8.5 inches. After the bottom of a jar has been covered with the cleanest sand obtainable, a tile is placed in it and the central perforation and the space between the periphery of the tile and the sides of the jar are filled with sand to the level of the upper surface of the tile. Filling these spaces is necessary, as the planulæ tend to settle in depressions. After this preparation, fresh sea-water is gently poured in through a funnel until the jar is nearly full. The extruded planulæ are pipetted from the vessel containing the parent colony and placed in the culture-jar prepared for their reception.

To get the best results, the water in the culture-jar should be changed at least once a day. This may be done by several devices. In order not to draw

off the planulæ, which are very small, a bag of fine-mesh bolting-cloth must be affixed to any tube used in withdrawing the stale water. One method was to siphon off the stale water with a rubber tube, the end of the tube inserted into the culture-jar having been drawn over one end of a glass tube, the other end of which is enveloped in a bolting-cloth bag. The table on which the culture-jars stand is provided with a gutter into which the water drawn off is discharged, ultimately flowing outside the building through a pipe through the floor. After a jar has been emptied to within an inch of the tile, it is refilled with fresh sea-water. This method causes a change in the level of the water, and by the pouring stirs up the unattached planulæ. A second method was to withdraw the old water by a glass siphon resting on the upper edge of the jar, the siphon having been rendered non-emptying by having its outer end bent upward. Fresh sea-water is added by a siphon extending to the bottom of the culture-jar from a supply-jar placed at a higher level. By this method a constant level is maintained in the culture-jars; the old water is drawn off from the top while the new water is added at the bottom. A third method was to have inside the culture-jar a tantalus siphon emptying through the side of the jar near its bottom. Fresh water is siphoned into the culture-jar from supply-jars placed at a higher level. When the water in a culture-jar has reached the level of the upper curvature of the siphon, it begins to run out and continues to flow until the level of the open end of the siphon in the jar is reached. The jar is then refilled by the afferent siphon until the level of the upper curvature of the tantalus siphon is again reached, when the water again begins to flow out. This method causes a rise and fall in the level of the water. A fourth method was to cut the bottom out of a culture-jar and to place the glass collar thus produced over a tile in a jar of larger diameter, the bottom of which had previously been covered with sand to a depth of an inch or slightly more. The tile and its surrounding collar are sunk into the sand until the upper surface of the tile and the upper surface of the sand are level with each other, while the level of the upper edge of the collar remains slightly higher than that of the inclosing jar. Water is siphoned into the collar from supply-jars, and filters through the sand filling the space between the collar and the side of the inclosing jar. When the level of the upper edge of the jar is reached, the water overflows. This method maintains a constant level of water, draws off old water at the bottom, and adds new water at the top.

As all four of these methods were tried, and as all were successful, the preference between them was not determined. Fresh water is necessary, and occasional stirring of unattached planulæ may be beneficial.

The two previous attempts to carry attached larvæ over from one year to the next failed. As it was discovered in 1908 that attached larvæ thrived in a floating live-car, it was decided to try to build a live-car strong enough to weather a hurricane, to load it with tiles bearing young polyps, and to anchor it securely. Two views of this live-car are here presented. One, plate 1, fig. C, shows its structure and the method of fastening the tiles; the other, plate 1, fig. D, shows the car after being placed in the water. Buoyancy was obtained by a closed copper tank in each end. The car is made fast to a sea-anchor by an anchor chain.*

*This live-car was sunk just before the hurricane of October 17–19, 1910, but was refloated, and, according to a report received from John Mills, the head mechanic of the laboratory, 6 tiles bore a total of 32 living polyps, or one-fifth of the polyps had survived the sinking of the car and the hurricane.

A

B

C

D

A, B. Two views of reef off Loggerhead Lighthouse, as seen at extreme low tide on June 6, 1910. Heads above water are *Orbicella annularis*. The alcyonarian *Rhipidogorgia flabellum* and *Plexaura* sp. are also shown.

C, D. Two views of storm-proof live-car in which tiles bearing attached planulæ were planted. C. Before launching, showing how tiles are fastened. D. After launching, showing its appearance in water.

Thirteen of the tiles to which planulæ had attached themselves were placed in this car on June 10. Dr. Mayer examined them on July 14 and forwarded the notes appearing in the fourth column of the following table.

Record of Tiles placed in Live-car anchored off Loggerhead Key.

No. of culture.	Name of species.	No. of polyps on tile.	Notes by Dr. Mayer on July 14, 1910.
1	Favia fragum I*	5	3 calices, each 2.5 mm. in diameter.
4	Porites clavaria I	20	
6	Favia fragum I	2	Larger calice 2.5 mm. in diameter.
8	fragum III	9	7 single and 1 double calice; largest 3 mm. in diameter.
10	Porites clavaria I	4	
11	clavaria I	3	
12	Agaricia crassa	3	
21	Porites clavaria 2 astreoides? 1	3	
22	astreoides I	2	Larger calice 2.75 mm. in diameter.
24	astreoides II	28	Larger calice 3 mm. in diameter.
25	astreoides II	70	29 colonies; largest 6 × 4 mm. composed of 8 polyps.
39	astreoides II	8	Largest calice 2 mm. in diameter.
41	astreoides	3	Largest calice 2.5 mm. in diameter.

*The Roman numerals refer to the parent colonies.

Dr. Mayer did not specifically report in his notes of July 14 on five of the tiles. These five include the four bearing young *Porites clavaria* and one bearing young *Agaricia crassa*. He says regarding them, "The five other tiles have only a few small corals on them." As the young polyps of *Porites clavaria* are so small that they can be seen with the naked eye only with difficulty and may easily be overlooked even with a reading-glass, and as there were originally only three polyps of *Agaricia*, Dr. Mayer's report is highly gratifying. But the outcome of the experiment is not yet known.

In order to check the favorableness or unfavorableness of the environment in a floating live-car for the life of the species of corals represented by the attached young in the live-car, 3 specimens of *Favia fragum*, 4 of *Agaricia crassa*, 1 of *Porites clavaria*, and 2 of *Porites astreoides* were taken from the reef whence the parent colonies came and were cemented to two tiles, which were also placed in the live-car alongside the young corals. Dr. Mayer reported on these specimens on July 14, that 2 colonies of *Agaricia* were about half dead; 1 *Favia* was dead, but the other 2 were thriving; the *Porites* were doing well, except a patch on one of the *P. astreoides* colonies.

The 8 other tiles were planted on iron stakes along the outer face of the northwest side of the Fort Jefferson moat wall, in water ranging at extreme low tide from 12 to 18 inches in depth. Only *Porites astreoides* is represented; 5 tiles bore the offspring of colony I, 22 young polyps, while 3 tiles bore the offspring of colony II, 21 young polyps.

A comparison of the number of attached young obtained from the different parents which gave out planulæ brings out interesting data showing the relative mortality of different stocks.

Number of attached Young obtained from the Different Parent Colonies.

Name of species and number of parent.	No. of attached young.	Name of species and number of parent.	No. of attached young.
Astrangia solitaria	0	Porites clavaria I	29
Favia fragum I	7	clavaria II, III, IV.	0
fragum II	0	astreoides I	24
fragum III	9	astreoides II	127
fragum IV	0	astreoides III	0

The parentage of four of the *Porites astreoides* planulæ was not definitely known; this was also the case with the one successful culture of *Agaricia crassa*, but the mortality of the young of this species is known to be high.

Definite conclusions on the vitality of the planulæ of different species and on the planulæ of different specimens of the same species perhaps can not be drawn from these data, but they are suggestive and the suggestions are here given. There is variation in the vitality of planulæ both between different species and between the planulæ of different colonies belonging to the same species. The planulæ of *Porites astreoides* are the hardiest; those of specimen II of this species were hardier than those of specimen I, while none of those of specimen III survived. Comparing species, *Favia fragum* furnished the next hardiest planulæ, two of four specimens yielding successful cultures; while from only one of four colonies of *Porites clavaria* were attached planulæ obtained. *Agaricia crassa* ranks about with *Porites clavaria*. It is important to obtain as complete data as possible on the vitality of planulæ and the duration of the free-swimming larval stage, as on them depend the ability of planulæ to be distributed by ocean currents.

Additional information was obtained on the duration of the free-swimming larval stage, but as a complete presentation of the data would necessitate a long table only a summary is given.

Duration of the Free-swimming Larval Stage in Experiments of 1910.

Name of species.	Duration of free-swimming stage.	Name of species.	Duration of free-swimming stage.
	Days.		*Days.*
Favia fragum	6 to 23	Porites clavaria	12 to 20
Agaricia crassa	11 to 17	astreoides	7 or 8 to 22

Most of the planulæ in culture 25, the one in which most larvæ became attached, attached themselves on the nineteenth day, or they were free 18 days. The planulæ in 41 cultures were extruded between May 18 and May 24. The water on some of them was first changed on May 28, on the 29th it was changed on all, and subsequently it was changed every day. As previous to May 28 only one planula had become attached, it is thought that the stale water may have prolonged the free-swimming stage.

The data for 1910 show longer duration of the free-swimming stage than did those for 1908 and 1909. Larvæ that can swim or float in the water from two to three weeks can be transported enormous distances by ocean currents. Madreporarian planulæ have frequently been obtained in the plankton tows off the Tortugas, clearly showing that these larvæ in that region come within the influence of the ocean currents.

Report of Prof. John B. Watson on the Work on Bird Key.

The past season was one very unfavorable for carrying out work upon distant orientation. The heavy storms in the Gulf region were the chief causes of the difficulties.

In 1907 the work upon the homing sense of the terns was incidental, whereas in the season just passed it was the principal feature. For this reason it was desirable to send out large numbers of birds. The shipping technique was very faulty until toward the very last. Twelve to fourteen

birds would be captured and marked and put into one cage. Under these conditions they injured themselves seriously by climbing over one another. Furthermore, some of the birds are shyer than others and will not feed unless individual attention is given. Late in the season it was found that if the large cage is divided into individual compartments the birds could be easily shipped. Minnows, too, are indispensable for keeping the birds in good condition. On some occasions it was found impossible to get minnows for the trip in Key West and large fish had to be carried and then chopped up at feeding-time. These precautions in shipping and in caring for the birds were not taken in the experiments made at New York, Galveston, and Mobile. Releases were made in all these harbors. The birds were invariably found in poor condition upon arrival—many of them dying *en route*. Furthermore, after every release the birds had to contend against cold weather and strong adverse winds. No birds returned from these ports.

a. Notwithstanding the failure to get returns from the above ports several important returns were obtained from intermediate points: Four sooties were carried from Bird Key and placed on a Mallory boat bound for New York. They were released *at night* (7^h 30^m p. m.) 365 miles from Bird Key. One bird returned at the end of 4 days. A second one, according to Mr. Wilson (a reliable employee of the laboratory), returned after my departure from the island—at the end of about 5 weeks.

b. Two noddies out of three returned from a distance of 460 miles due west of Bird Key. The time required was 3 days. This is probably the most important record ever obtained in the homing work. The journey was made entirely over water (the place of release was about midway between Galveston and Key West), with no possible object to serve as a visual landmark. Four sooties released with the noddies did not return. (See *f*.)

c. Twenty-four noddies and sooties were released at Key West, 65.25 miles from Bird Key. Twenty-two returned—twelve out of twelve noddies and ten out of twelve sooties. The time of the noddies varied from 17.5 hours to 2 days 15 hours. Three of the sooties returned at the end of 17.5 hours; two required 1 day 20.5 hours, while the remaining ones required 5, 6, 8, 9, and 11 days respectively. This flight is of interest in showing such a large percentage of returns and the varying times of those returns. It is of further interest in showing that the nest mate and nest locality are recognized and claimed after an interval of several days.

d. An attempt was made to determine the speed of flight. Three noddies which had already been over the route to Bird Key from Key West were again shipped to Key West and released at 1^h 30^m p. m. All three returned to the island at 5^h 45^m p. m. of the same day. They returned just as the other birds were coming in from the feeding-grounds for the night. It is probable that the three birds flew back until familiar waters were reached and then stopped to feed.

e. Cyon's well-known hypothesis of a special nasal sense was tested. The anterior nares of two birds were tightly plugged with wax and then coated heavily with asphaltum. They were released at Key West at 1^h 30^m p. m. Both were on the nest at daylight of the following morning. Examination showed that the nostrils were still tightly closed. The asphaltum had not even been scratched. The birds were in very good condition. This entirely upsets Cyon's theory so far as the terns are concerned.

f. Exhaustive experiments were made upon the water-habits of the birds. Both species can swim in, rest on, and fly up from the water. If the two species are confined in a large cage partially sunk in the water, it is found that

the *noddies* can pass the *whole night* in the water and still arise from it in the morning. The sooties, on the contrary, perish in nearly every case if forced to remain long in the water. If, however, small wooden floats are left in the water, the sooties immediately utilize them and can spend the whole night under such conditions, and be little the worse for the experience on the following morning.

It follows from these experiments that the sooties can not be expected to return over water from a distance greater than that which can be covered in a day's flight. If the bird were lucky enough to meet with driftwood at the proper time it would doubtless survive. The noddies are not so limited in their water capacities. We yet have hopes of getting returns from Galveston and Mobile with them.

Report of Prof. Dr. E. Jörgensen, of the Cathedral School of Bergen, Norway.

My visit to the marine laboratory at the Tortugas occupied three weeks and a half, during which time I was engaged in a life-study of the *Peridinea.*

As the laboratory is somewhat near the Gulf Stream, a thorough examination of the plankton there should be of more than usual importance, for it would give one the opportunity to compare the Gulf Stream plankton with that of the seas of northern Europe. On the whole, the plankton of the Tortugas is rather rich, considering its subtropical situation and the well-known fact that the plankton of the tropical and subtropical regions is often very poor as to quantity. Some of the groups of the *Peridinea* were well represented, while others occurred only sparingly. There were only few *Ceratia,* so that the material was scarcely sufficient for the decision of several important questions; for instance, the manner in which active motion of these forms is produced. It is well known that the *Ceratia* are highly differentiated drifting organisms; their often strikingly "luxuriant" and remarkable forms are produced (as a more thorough examination will show) by more or less perfect adaptations to their life as passively drifting organisms.

The more perfect this adaptation the more closely will the cell be confined to the particle of water in which it is living; therefore it should *a priori* seem probable that the forms provided with floating apparatus and on the whole best adapted to drifting in the water should be those least capable of active motions. This should especially be true concerning the power of rotation, which in highly specialized floating forms may be expected to be greatly reduced. According to my experience, from the small amount of material obtained at the Tortugas, the *Ceratia* really seems, from a state of active movability in the lower forms, to have developed to a passive drifting in the higher, and this to such a degree that I was not able to make out any active power of motion by the long-horned forms. It should, however, be stated that the *Peridinea* are usually very difficult to keep alive and do not well endure being placed on an object-glass for direct study under the microscope. It would therefore be rather rash to declare that the specialized floating forms of *Ceratia* have really lost all their power of active motion, yet it would seem safe to conclude that the long-horned species have lost more or less completely their power of rotation, especially such forms as *C. trichoceros* and *C. tenue.*

Several species of the genus *Peridinium* were studied. This genus is a difficult one and includes a great many species, very few of which have as yet been defined with sufficient accuracy.

Among other interesting *Peridinea* I found *Blepharocysta splendor maris* and *Ceratocorys* (=*Dinophysis*) *jourdani* to be very plentiful. The latter species is of special importance, as Dr. Cutzjun attempts to prove it to be a connecting link between the two otherwise very different genera *Phalacroma* and *Ceratocorys*.

Entz has rather pointedly defined his understanding of it in naming it *Phalacroma ceratocorys*, including herein both *Phalacroma jourdani* and *Ceratocorys horrida;* he considers it a *Phalacroma* that changes into a *Ceratocorys*. In spite of the interesting observations and figures given by him, I have always considered this to be rather incredible.

The genus *Phalacroma* is a typical genus of the Dinophysidæ, with a regular longitudinal division of the shell along a sagittal suture into two essentially symmetrical halves (a right and a left one), while *Ceratocorys* belongs to the Peridinidæ, has no sagittal suture, and is obliquely divided into two asymmetrical parts. After an examination of numerous specimens I came, however, to the conclusion that *Dinophysis jourdani*—which Dr. Schütt referred to the genus *Phalacroma*—is a genuine *Ceratocorys*, but a species different from the common tropical *C. horrida*, although the species may be easily mistaken for a *Dinophysis* or *Phalacroma*. The other larger species, *Ceratocorys horrida*, was rare at the Tortugas, and when found was usually far out toward the border of the Gulf Stream. I have not observed intermediate forms between the two species.

At the Tortugas I also met with a peculiar species of *Peridinea*, that has been described and figured by Gourret under the name of *Postprorocentrum maximum*. Gourret considered it to be related to Ehrenberg's genus *Prorocentrum*, which it somewhat resembles. Later on, the same species seems to have been described by Dr. Joh. Schmidt, of Copenhagen, as *Ostreopsis siamensis*. Dr. Schmidt also found most of the plates of the shell, showing that it belongs to the Peridinidæ, not to the Adinidæ, such as *Prorocentrum*, and is somewhat remotely related to the genus *Gouyaulax*. Like the species of this latter genus, it also possesses numerous brownish yellow (diatomine-colored) chromatophores.

Occasionally I observed some specimens of *Pyrocystis pseudonoctiluca*, especially toward the border of the Gulf Stream, but did not succeed in keeping them alive sufficiently long to be able to discover whether it developed from spherical to crescent-shaped cells. I also found a species, for which I shall propose the name *P. claparèdei*, for the *Gymnodinium lunula* of Schütt is a different warm-water species with a single larger gymnodinium in each crescent-shaped cell. Such cells as the latter I observed at the Tortugas, but only seldom, and it seems probable that they belong to *Pyrocystis pseudonoctiluca* as a stage of development. The other species of *Pyrocystis* occurred only very rarely at the Tortugas.

Further, I observed a most remarkable fact about a very widely distributed organism, the systematic position of which has not yet been finally determined, viz, *Spermatogonia antiqua*. It is a protozoon with long, stout spines, reminding one of those of radiolaria of the groups *Acanthometra;* Cleve therefore referred it to the radiolaria. The organism seems to be cosmopolitan, occurring not only at Tortugas, but also off the coast of Norway. It seems, however, to be more common in the warmer seas. It possesses a nucleus or a similar body of a short, sausage-like shape and a peculiar, very coarse structure. It differs from the radiolaria in possessing no central capsule. To my great astonishment, I twice observed that living specimens are able to move their spines suddenly and simultaneously toward one an-

other, so that their distal ends diverge less than before; then they move back again, and so on, so that it appears that the cell pushes its way through the water by means of the spines.

The axis of the Gulf Stream is so far from the Tortugas that I could collect there only rarely, although near the edge of the Stream there is a different plankton, containing some of the rarer tropical forms, as *Heterodinium*, species of *Orinthocercus, Centrodinium,* and large species of *Peridinium.* In the immediate region of the Tortugas the water was quite shallow, and this shallow coast water did not seem to afford suitable conditions for the development of *Peridinea.*

DEPARTMENT OF MERIDIAN ASTROMETRY.*

LEWIS BOSS, DIRECTOR.

The headquarters of the Department of Meridian Astrometry is located at the Dudley Observatory, Albany, New York. A branch observatory has been established at San Luis, in the Argentine Republic, as described in the reports of the Department for 1908 and 1909.

The activities of the Department in the line of observation have been wholly transferred to San Luis for the present. That station is in charge of Prof. Richard H. Tucker, with Mr. A. J. Roy as chief assistant, and is devoted to observations of far southern stars with the meridian-circle of the Dudley Observatory, as described in previous reports.

The work of the Department, as already stated, includes for the time being no observations at Albany. During the past year operations at Albany have been carried on mainly in three lines.

a. Preparatory computation for the General Catalogue of Stars down to the seventh magnitude.
b. Computations relative to the observations reported from San Luis.
c. Publication of the Preliminary General Catalogue, preparation of a general catalogue of standard stars for 1910, and studies upon systematic proper motion, as derived from the individual values of motion contained in the Preliminary General Catalogue.

Under the first head, ephemerides for all the stars to comprise the proposed catalogue of about 25,000 stars (which I call the General Catalogue) are completed in such a manner that an accurate comparison of them with the results of observation in each case can be readily made after the material from the later observations becomes available for use. Much progress has also been made in comparing the results of all published observations with these ephemerides.

Comment on the progress made under the second head—preliminary reductions and tests of the observations made at San Luis—is deferred to a later paragraph of this report.

Under the third head it may be stated that the Preliminary General Catalogue of 6,188 stars was published in March 1910. The Department acquired 200 copies, most of which have been presented to students of stellar problems and to the principal observatories engaged in stellar observations. Much of my personal attention has been given to the proof-sheets of this work, which it was desirable to have specially free from errors.

During the summer and autumn months of 1909, and in connection with consultations with other members of the committee on proposed fundamental observations desired by the Paris Congress of April 1909, a "List of 1,059

* Address, Dudley Observatory, Albany, N. Y. Grant No. 605. $35,655 for investigations and maintenance during 1910. (For previous reports see Year Books Nos. 2–8.)

standard stars for 1910" was prepared by me, was published by the Dudley Observatory, and a few copies were circulated in January 1910. This list of standard stars is the result of a careful selection from a much larger list of standard stars which we have been using in observations with our meridian-circle, both at Albany and San Luis. In giving the positions and motions for 1910, we have used the Preliminary General Catalogue for 1900 as the basis. The object was to prepare a larger list of the standard stars homogeneous in character, which can most rapidly and economically be perfected by further observation. Nearly all of these south of —20° have already been observed at least 12 times at San Luis. In making these selections the requirements of safe prediction have been specially regarded.

STUDIES UPON STELLAR MOTION.

The position of the apex of solar motion, the general parallactic drift of the stars, the probable value of the precession, and the probable amount of the motion of the equinox are all problems concerned in the apparent systematic motions of the stars. These had first to be considered and eliminated before we could proceed to a closer study of special forms of systematic drift should such exist.

In my report for 1909 I gave an outline of the results of our studies upon the general systematic motions, or drift. These points have been subjected to further examination, analysis, and extension during the past year, and an outline of processes employed and of results attained have been published in Nos. 612 and 614 of the Astronomical Journal. The preliminary result has been reached that the general systematic motions of the stars, as we find them to be in our Preliminary General Catalogue, are not inconsistent with the hypothesis of random motion of the individual stars, or at least with a symmetrical distribution of the motions around a conventional origin.

In the course of discussion, however, it was found that the mean of apparent stellar motions distinctly varies with distance from the Galactic plane, and increases decidedly with Galactic latitude. This result completely establishes the results of previous researches of a less comprehensive scope.

It is also shown (Ast. Jour., 614, p. 122) that the parallactic drift in the plane of the Galaxy is probably greater, in proportion to the mean motion of the stars therein, than it is in the higher Galactic latitudes. One explanation of this phenomenon was naturally suggested at once. The mean motions peculiar to the stars themselves, for a part of those in the vicinity of the plane of the Milky Way (Galaxy), might be smaller in linear velocity than those in the higher Galactic latitudes. It was, in fact, pointed out, some eight years ago, by Professor Frost (Publ. Yerkes Observatory, vol. II, Radial Velocities of Twenty Stars, p. 105) that the radial velocities of 20 stars of the *Orion* type are in the mean only 7.0 km. This is much less than half of the means for all types. Additional testimony to the same effect has accumulated since. Our Catalogue contains 525 stars of the *Orion* type

(B to B_5), and of these 472 have Galactic latitude less than 30°, and 244 have latitude less than 10°.

This and other indications seemed to render it necessary that in our further examination of evidences of systematic motion we should take into account the principal types of stellar spectra.

Furthermore, we find evidence which seems to indicate, on the part of the larger motions at least, a tendency in those motions to have comparatively small inclinations to the plane of the Galaxy.

We are now proceeding to test these and other points bearing upon our general hypotheses. The necessity of pushing reductions of the observations reported from San Luis greatly restricts the amount of time we can devote to these important researches. In fact, it is becoming more and more evident that the facts of observation which we are hoping to accumulate in the larger General Catalogue will soon be urgently needed to establish more accurately what degree of confidence shall attach to various promising hypotheses that are constantly cropping up in relation to the mechanism of the stellar universe, for the proper examination of which the existing material is showing itself to be inadequate in the number of stars.

OBSERVATIONS AT SAN LUIS.

In the Year Book for 1909 (pp. 154–158) some account was given of the work of installing the Olcott meridian-circle in San Luis, Argentina, and of the observations thereupon begun April 6, 1909.

The remarkable rate of observations reported as prevailing up to the close of the record in August 1909, so far from falling off, became even somewhat accelerated. At the end of the first full year of observations, April 1, 1910, more than 60,000 observations had been obtained. The latest date for which I have a report of the count is August 1, 1910. At that date the total for 16 months, which includes observations of the nadir, was, in round numbers, 78,000, of which the share of each observer at the telescope was approximately as follows: R. H. Tucker, 17,700; A. J. Roy, 19,800; W. B. Varnum, 20,400; M. L. Zimmer, 11,000; R. F. Sanford, 9,100.

The instrumental circumstances of observation are conveniently designated as follows: E and W indicate whether the clamp of the instrument was east or west. Reversal took place about once a month. A or B indicate whether the circle A (next the clamp) or B, respectively, was employed in observation. Alternation in the employment of circles took place about midway between reversals. The 78,000 observations were almost equally distributed in the four circumstances of the instrument: AE, AW, BE, and BW.

The observers usually worked in two shifts on each night, each consisting of an observer at the telescope and another at the microscopes. Sometimes, in the crowded parts of the list, a third assistant was employed in making the settings. Up to August 1, 563 series had been observed on 369 nights. The average number of observations in each series was a little under 140. It was

the practice of the three fundamental observers, Tucker, Roy, and Varnum, to make some observations in the late afternoon, but the principal part of them in the first half of the night. Observations were also made by them for a short time in the morning in order to secure a group of fundamental stars, approximately 12 hours later than observations of fundamental stars the evening before, and at the same time to obtain transits of close-polar stars, successively above and below pole, in order to determine the azimuth of the instrument, independently of any knowledge of the right-ascension of any polar stars. The office of the groups of fundamental stars, approximately 12 hours apart, is to obtain corrections of the "clock-stars" free from diurnal period. The fundamental observers also observed for determination of the standard stars in all zenith-distances from about 80° north to 80° south, and aimed to obtain, in one class 8 and in another class 12 observations each. As they had opportunity, they also observed for determination of the places of those stars that are brighter than the seventh magnitude, or that are contained in La Caille's zone-catalogue for 1750. Each of these stars, not included in the classes of standards, was scheduled to have four observations.

Each of the three fundamental observers was assigned to primary observations for one week and was then followed by another, who assumed the responsibility for all primary observations during the next week. Quite frequently the fundamental observers not on duty with primary observations were engaged during the last half of the night on secondary observations. The observers Zimmer and Sanford were always engaged on secondary observations, and usually for the later hours of the night.

While one observer was engaged at the telescope, another read the microscopes, recording the indications of each of the four microscopes at each setting. Following was the approximate number recorded by each of the readers: Fair, 12,000; Delavan, 16,000; M. I. Roy, 3,500; Mearns, 14,500; Jenkins, 16,500; Sanford, 6,300; Zimmer, 4,800; fundamental and miscellaneous, 4,400.

Almost invariably the chronograph sheets were read off on the day following observations, so that the observing list could be carefully checked off, and observations superfluous to the program avoided. Computation of the wire-intervals and of the inclination of zenith-distance wire were kept nearly up to date. Nearly 2,600 sets for wire-intervals have been obtained in all, about equally in the two clamps. In the first 334 series 725 determinations of magnitude-equation were made by the five telescope observers—mainly by the three fundamental observers. Up to July 4, 1910, from 40 to 70 single determinations of the difference of transit north minus south were made by each observer, or 270 in all. This part of the work is still considerably in arrears.

As soon as the first general determination of wire-intervals was obtained, the staff in San Luis applied the results to the reduction of transits to mean wire.

The means of the microscopes and the application of the correction for errors of runs were currently made.

Then began the preparation of copies of the observing record to be sent to Albany. This included the name, the approximate position, and the magnitude of the star observed, with the concluded mean transit; in zenith-distance the means of the four microscopes corrected for runs and graduation-error, together with designation of the point in the field where bisection took place.

This record was finally dispatched to Albany by registered mail, and up to the present writing has reached series 253. It is proposed to continue the dispatch of this record to Albany until the whole of it has been received, before sending the original observing record made at the instrument. As security for the transit record, the forms upon which the transits were recorded from the chronograph sheets are arriving by registered mail, and the chronograph sheets will accompany the observing books, at the end, as part of the original record.

In the same way copies of the readings for instrumental record and for the refraction-arguments are sent to Albany in advance, so that when the instrument is taken down it will be known that complete copies of the record have been received in Albany as security for the preservation of the result.

As explained in previous reports, the plan of observing at San Luis (four times each in the minimum) our standard stars situated between —20° and + 49° was adopted in order to get material for constituting a firm connection between the observatories at Albany and San Luis. Corresponding measures are to be taken at Albany. Thus it is expected to determine a constant correction to the adopted flexure-correction of the instrument and those values of the refraction constant at each observatory that will best harmonize the results from the two stations. The following statement exhibits the progress made in determining the positions of stars at large north zenith-distance at San Luis:

Declination.	Zenith-distance.	No. of observations.	No. of stars.
+35° to +40°	68° to 73°	400	46
+40 to +45	73 to 78	500	50
+45 to +49	88 to 82	300	31

While the latitude at San Luis, according to concurrent experience, is too small to permit of a reliable independent determination of the refraction from circumpolar observations alone, it has been thought best to provide a large number of observations below the pole that may serve to strengthen the determination otherwise obtained. For other reasons the observations below pole are very numerous down to 66° of zenith-distance. Beyond that we have:

Zenith-distance.	No. of observations.	No. of stars.
67° to 72°	500	50
72 to 77	500	68
77 to 82	600	92

Unfortunately, the conditions of observation at San Luis at zenith-distances much over 65° seem to be very unfavorable, both on account of the definition and the unsteadiness; in fact, the unsteadiness at all zenith-distances, according to the unanimous testimony of the observers having experience of both places, Albany and San Luis, is distinctly more troublesome at the latter.

At the same time, the accuracy of the observations at ordinary zenith-distances does not seem to be so much impaired as one might have supposed. This appears to be substantiated by the preliminary reductions already made at Albany, and is in accordance with experience elsewhere, except when very special accuracy in observation of a very few stars is attempted.

As a general check on the direct observations, about 400 observations by reflection have been secured by the fundamental observers; but they are not included in the foregoing count. Owing to the prevalence of wind at San Luis the observers are not sanguine as to the quality of these observations.

COMPUTATIONS UPON OBSERVATIONS.

Computation of reductions to apparent-place and of tabular correction for refraction have been occupying a large part of the attention of the computing staff at Albany since the beginning of the arrival of the instrumental record, to which allusion has been made. None of this could be sent until several months of observation had been accumulated.

The Director has given a great deal of attention to test-reduction, as well as to parts of the reduction that are semi-definitive. None of the systematic treatment of the work can be considered definitive until practically the whole of the observations are under consideration. The tests have gone far enough, however, to indicate that the instrument, from month to month, is very steady indeed, and that, although some of the diurnal changes are distinct, they are also in general very small. The determination of the level by the nadir observations seems to be precise in a gratifying degree, so that it is possible to detect a very minute diurnal variation which could not have been very certainly shown with less precise observations. The standard collination appears to be very permanent except when adjustments have been purposely made. A small change with the temperature is closely marked and precisely determined.

In relation to the azimuth it is not possible to decide upon the true character of its variations. The changes in this coordinate appear to be larger and less regular in the nadir, though not pronounced from month to month. Much labor has been expended by the Director personally upon this subject. His investigations have proceeded far enough to indicate that the outlook for systematically accurate results in this respect is good when all the material of special observation for systematic constants shall be at hand.

As stated previously, the observations have been tested extensively for their quality in the differential sense. In this respect they appear to correspond well with the standard toward which we aimed. This standard did not propose competition with special observations where the highest accuracy has been attained upon comparatively few objects. It aimed at attaining, in the differential sense, good rank among the best modern collections of obser-

vations containing a large number of stars; and there is every prospect that such rank will be reached. If this opinion should be verified it will become a remarkable tribute to the skill and to the intensity of application of the observers who have made a record of such unprecedented proportions as to the rate of observations. This rate is somewhat greater than 4,800 per month for 16 months—twice the highest previous rate known to the Director in this class of observations and about five times the ordinary rate. On the other hand, there were always seven observers, and for a short time there were ten. Moreover, the annual number of clear nights was 280, and a large proportion of these were clear from sunset to sunrise.

Furthermore, practically the entire energy was devoted to observations alone and to such preliminary operations as were necessary to furnish the record that should be the basis of the general reduction. Naturally this work has proved very exhausting and the strain has been decidedly felt by at least one-half of the observers. At the outset of the work the Director hazarded the proposition that it might be possible to secure 30,000 observations in each of the second and third years. That this rate should have been doubled was due to a unanimous and irresistible determination on the part of the observers themselves to shorten the period of observations.

It is believed that it will be possible to complete the entire work and to take down the meridian-circle some time in the early part of 1911. At the present writing less than 5,000 observations in the regular program remain to be made. There is still a small program of observations required to complete the investigation of certain constants of importance in the systematic sense.

Arrangements are not now fully made for attending to the photometry of the fainter stars of the observing list. This was a part of the original design, but in the rush of meridian observations there never seemed to be a time when it could be advantageously started. The prosecution of that work, however, would require only two observers, and it could probably be completed within one year.

THE STAFF.

At the present writing (aside from the Director) the staff consists of 15 persons regularly employed. There is one group consisting of 8 persons at Albany, and another of 7 at San Luis. Besides these, there is a varying number of computers (at present 9) working upon apparent-place computations on the piece-work plan.

MOUNT WILSON SOLAR OBSERVATORY.*

WALTER S. ADAMS, ACTING DIRECTOR.

The past year has been a most active one in the history of the Solar Observatory from the standpoint of the investigations in progress. The continuation of the study of magnetic fields in the sun has gathered about it many allied investigations involving both laboratory and solar results, and similarly studies of the spectrum of the sun's limb, of the solar chromosphere, and of the circulation of the gases in the sun's atmosphere have developed numerous related problems. On the side of stellar research the efficiency of the 60-inch reflecting telescope for many lines of investigation has led to the inclusion of a constantly increasing number of additional subjects in its program of observational work.

Among the main results of investigations conducted during the past year the following are to be included:

(1) The classification of sun-spots according to the properties of their magnetic fields.

(2) The development of a method of mapping magnetic fields over the entire solar surface.

(3) Additional proof has been found of the rotation of the plane of polarization, sometimes known as the Faraday effect, in certain spots.

(4) The continuation of the measurement of the areas of the calcium flocculi has served to furnish an index of the solar-activity and to confirm the relationship between it and the changes in the earth's magnetic field.

(5) An extended study of the circulation of the calcium-vapor in the solar atmosphere indicates a motion of ascent for the gas producing the bright lines H_2 and K_2 and a descending motion for the gas producing the dark lines H_3 and K_3. The motions are radial with reference to the sun's surface.

(6) The study of the dark hydrogen flocculi with high dispersion has strengthened the view that they are to be considered as regions of increased absorption.

(7) The measurement of the displacements of the spectrum lines at the sun's limb has led to the conclusion that they are probably due mainly to pressure. The enhanced lines show systematically larger shifts than do the arc lines, and the elements of low atomic weight show smaller shifts than those of higher weight.

(8) About 1,200 bright lines in the spectrum of the sun's chromosphere have been photographed and their wave-lengths measured. No evidence is found of systematic differences in wave-length from the dark lines of the solar spectrum.

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* Situated on Mount Wilson, California. Grant No. 607. $105,720 for construction, investigations, and maintenance during 1910. (For previous reports see Year Books Nos. 3–8, inclusive.)

One Hundred and Fifty Foot Tower Telescope on Mount Wilson, October 1910.

(9) The measurement of several photographs of the spectra of the opposite edges of the sun indicates that no appreciable change has taken place in the sun's period of rotation since 1908.

(10) Direct photographs of certain of the star-clusters and spiral nebulæ show an immense amount of detail hitherto unknown. In particular the spiral nebulæ are found to contain great numbers of nebulous stars enveloped in the curved streamers.

(11) Spectra of several of the brighter stars have been obtained with the 18-foot spectrograph and the 60-inch reflector. The measurement of the photographs indicates that the enhanced lines in the spectra of *Sirius* and *Procyon* are shifted toward longer wave-lengths relative to the arc-lines. An investigation of the spectrum of *Arcturus* shows a relationship among the displacements of the lines due to different elements similar to that found at the sun's edge. The effect is probably due to pressure.

(12) A low-dispersion spectrograph containing one prism has been used at the primary focus of the 60-inch reflector since September 1909 for the determination of radial velocities of stars and the classification of spectra. With this instrument the spectrum of a star of the solar type of 8.0 visual magnitude may be photographed in 70 minutes.

(13) The spectra of four spiral nebulæ and of nine star clusters have been photographed with a low-dispersion spectrograph. The spectrum of all of the spiral nebulæ investigated is approximately of the G type, and that of the globular star clusters of the F type.

(14) Experiments with diaphragms of varying aperture on the 60-inch reflector have indicated that the effects of diffraction are essentially negligible in their influence on the brightness of the star images. In view of the results obtained it seems reasonably probable that by this simple means an absolute scale of photographic stellar magnitudes may be obtained which will be satisfactory within a wide range of brightness.

(15) A statistical study of the motions of certain stars of the *Orion* type of spectrum points to the existence of systematic motion on the part of two large groups of stars situated in *Scorpius* and *Perseus*. The motions are in opposite directions, and the groups probably form part of two main stellar streams.

(16) An extensive laboratory investigation of the Zeeman effect for iron, chromium, and titanium, and comparison with pressure displacements, has shown that no direct quantitative relationship appears to exist between the amount of separation and the pressure-shift.

(17) The Zeeman effect for vanadium and nickel has also been investigated for purposes of comparison with sun-spot spectra, and the lines have been classified according to their type of separation in the magnetic field.

(18) Photographs of the spectrum of the electric spark under pressure have shown that the enhanced lines remain bright under a pressure at which the great majority of the remaining lines are reversed. An application has been made of this result to the spectrum of the solar chromosphere.

(19) Measurements of the photographs of the spectrum of the spark under pressure indicate that at the same pressure the enhanced lines are displaced considerably more than the great majority of the arc lines.

References will be made to numerous other investigations in the course of the discussion of the work now in progress.

One of the most important of the researches of the past year, particularly in its wide bearing on the future work of the 60-inch reflector, has been that of Professor Kapteyn on the systematic motions of groups of stars. Perhaps the greatest difficulty in the construction of an outline of work for a large telescope is that of coordinating the various kinds of observations and making them so far as possible lead toward the same end. By his discovery of a common motion among stars of certain groups, Professor Kapteyn has given to the study of the radial velocities of the fainter stars a definiteness of purpose which is perhaps commensurable in importance with the value of the discovery itself.

STAFF.

There have been few changes in the staff of the Observatory during the past year. Mr. Adams has served as Acting Director during the absence of the Director, and has been engaged in the organization of the stellar spectroscopic work. Prof. F. H. Seares has continued as superintendent of the computing division throughout the year and has had editorial charge of the Observatory publications. He has also carried on certain photometric investigations with the 60-inch reflector. Dr. Arthur S. King has remained in charge of the physical laboratory. Prof. G. W. Ritchey has continued to devote a part of his time to the design of the 100-inch reflecting telescope, and part to direct photography with the 60-inch reflector. Prof. C. E. St. John has been engaged in an investigation of the motion of the calcium vapor in the sun's atmosphere and in a study of the radial motion in sun-spots. Mr. Ferdinand Ellerman has continued the observations with the spectroheliographs of the Snow and tower telescopes, and has also taken numerous photographs of spectra with the tower telescope. Mr. H. D. Babcock has divided his time between spectroscopic work in the Pasadena laboratory and photography of stellar spectra with the 60-inch reflector. He has also taken many spectra of sun-spots with especial reference to the determination of the direction of polarization of the spectrum-lines. Dr. E. A. Fath has been engaged in photographing the spectra of certain spiral nebulæ and star-clusters, and has also secured photographs of some of the Kapteyn selected areas. Dr. C. M. Olmstead resigned from the staff in October 1910.

Prof. J. C. Kapteyn, of the University of Groningen, Research Associate of the Carnegie Institution of Washington, has been at the Observatory since July, engaged in making certain statistical studies of star-groups, and in planning a considerable part of the work of the 60-inch reflector. Dr. H. G. Gale, of the University of Chicago, Research Associate of the Carnegie Institution of Washington, spent the months of April, May, and June

in Pasadena, and made an investigation of the displacements of the spark lines under pressure in the physical laboratory. M. Henri Chrétien, of the Observatory of Nice, spent the months between February and September on Mount Wilson and in Pasadena, and carried on a large amount of observational work on the sun. Visits from astronomers and physicists passing through Los Angeles have been frequent during the year.

Mr. Abbot, of the Smithsonian Institution, has been continuing since May his investigations of the solar radiation at his permanent observatory station on Mount Wilson. During a special expedition by Mr. Abbot to Mount Whitney in August, his work was conducted on Mount Wilson by Mr. F. E. Fowle, of the Smithsonian Institution.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

Direct Photography of the Sun.

Direct photographs of the sun have been taken on practically all of the clear days during the past year. These plates, besides furnishing a valuable record of the condition of the sun's surface, have been most useful during the past year in the study of the structure surrounding sun-spots.

Work with the Spectroheliograph.

The work of the year with the spectroheliograph has comprised:

(1) Daily photography of the sun with the Snow telescope and 5-foot spectroheliograph. The greater part of this work has been carried on by Mr. Ellerman, but during his absence in Hawaii from March until July for the purpose of photographing Halley's comet, the observations were continued by M. Chrétien. During the year photographs have been made on 289 days, and 793 spectroheliograms of the solar disk with H_1, H_2, $H\alpha$, $H\beta$, $H\gamma$, and $H\delta$, and of prominences at the limb with $H\alpha$, have been obtained.

(2) Photography of the sun with the 60-foot tower telescope and 30-foot spectroheliograph by Mr. Hale and Mr. Ellerman. This work included the use of H_3, K_3, D_2, and other narrower lines; the center, edges, and wings of $H\alpha$, $H\beta$, $H\gamma$, and $H\delta$; lines widened in spots, etc.

(3) Studies of spectroheliograph plates by Mr. Hale and Miss Smith. The purpose of this work is to investigate the life-histories of sun-spots and accompanying faculæ and flocculi, in connection with Mr. Hale's researches on solar magnetism. The plan now followed includes:

A. An examination of direct photographs of the sun (photoheliograms) giving (*a*) appearance and distribution of the faculæ; (*b*) approximate heliocentric coordinates of spots; (*c*) area of spots; (*d*) classification according to Cortie; (*e*) curvature of the penumbral filaments.

B. Study of the calcium flocculi on H_2 plates, giving their (*a*) area, (*b*) distribution, and (*c*) approximate intensity.

C. Study of the hydrogen flocculi on $H\alpha$ and, in some cases, $H\beta$, $H\gamma$, and $H\delta$ photographs, with especial reference to (*a*) the appearance and changes

of the vortex structure, classified as unipolar, bipolar, or multipolar; (*b*) bright *Hα* structure about spots; (*c*) eruptions; (*d*) filaments, and the angle they make with the equator; (*e*) angle between the axis of the multipolar *Hα* flocculi and the equator.

The characteristic forms of the *Hα* flocculi and the discovery that the two larger spots lying at opposite ends of a group are usually, if not always, of opposite polarity, led to the classification of the *Hα* flocculi as (1) unipolar (a single spot or bright flocculus surrounded by simple vortex structure, right-handed, left-handed, or radial); (2) bipolar (spot group or two spots—one sometimes absent or replaced by bright flocculus—surrounded by *Hα* flocculi resembling in form the lines of force connecting the opposite poles of a bar magnet); (3) multipolar (spot group surrounded by curved *Hα* flocculi of special form); (4) filaments (very dark, usually long and narrow); and (5) eruptions (very bright, rapidly changing in form). This classification with some subdivisions will include most of the more characteristic flocculi.

A study of 29 spots in the early stage of formation indicates that the first sign of activity is given by the appearance of bright *Hα* flocculi in the spot region with or without dark filaments, and with or without disturbances in the surrounding region. As the spot develops the surrounding disturbance appears or increases, and the vortex structure usually presents itself. In the bipolar type the bright flocculi are usually seen first between the spots, while in the other cases they are closely massed about the spot or group. This favors the hypothesis, based upon observation of the magnetic phenomena, that the two principal spots of a bipolar group are the opposite extremities of a single vortex tube.

The characteristic structure on which the above system of classification is based appears much more clearly on *Hα* photographs than on those taken with *Hβ*, *Hγ*, *Hδ*, or H_2. On *Hδ* plates, made with the 5-foot spectroheliograph, the unipolar and bipolar type can be distinguished in some cases, but no good example of the multipolar type has been found as yet. The general form of the bipolar type is roughly indicated on these calcium photographs, and in one or two instances the unipolar type appears, but the multipolar type is absent. On photoheliograms the form of the penumbral filaments recalls the unipolar structure of the *Hα* flocculi, and the faculæ follow roughly the outline of the bipolar type.

The above results, confirmed by photographs taken with different parts of the *Hα*, *Hβ*, *Hγ*, and *Hδ* lines, indicate that the vortex structure of the flocculi is best shown at comparatively high levels in the solar atmosphere. The relationship of this structure to that of the penumbral filaments is under investigation.

The long axis of multipolar flocculi has been found, in 38 examples, to be nearly parallel to the solar equator and to coincide very nearly with the axis of the inclosed spot groups.

Hα Flocculi around spots of the Bipolar type.

Of 145 dark *Hα* filaments, 84 make an angle of less than 45° with the solar equator, while 61 are inclined from 45° to 90° to the equator.

The completion of the 75-foot spectroheliograph of the new tower telescope, which is now under construction, should permit this work to be extended considerably.

Spectra of Sun-spots.

The study of solar magnetism, rendered possible by the detection of the Zeeman effect in sun-spots, has been continued throughout the year, in so far as the decreasing solar activity has permitted. A point of especial interest is the determination of the polarities of the various spots in groups. Photographs of the spectra of the several umbras and penumbras, made in rapid succession by setting different parts of the group on the slit of the spectrograph, give the polarity and the strength of magnetic field at all points crossed by the slit. The magnetic survey of the solar surface begun in this way will soon be greatly facilitated by the use of special polarizing apparatus with a multiple slit, so constructed as to permit the spectra of six or eight contiguous regions to be photographed simultaneously.

The results already obtained show that the polarity of the numerous small spots in a group is not necessarily the same as that of the largest spot, even though all lie within the same penumbra. The polarity of the large penumbra, however, seems to be determined by that of the principal umbra. In the case which is frequently observed of a group consisting of two principal spots, with or without accompanying small spots, the two spots are usually, probably always, of opposite polarity. As already remarked, the configuration of the *Hα* flocculi about such a group closely resembles that of iron filings in the field of a bar magnet.

In the classification of sun-spot lines provision has been made for the inclusion of resolved and unresolved triplets and quadruplets, and of more complex types as well. A number of cases of asymmetrical lines and of parallel and convergent lines in the same spectrum have also been detected.

The observational work with the 60-foot tower telescope and 30-foot spectrograph by Messrs. Hale, Ellerman, and Babcock includes the determination of polarity and field strength for all spots of sufficient size. The study of the photographs by Mr. Hale, Mr. Babcock, and Miss Burwell has been carried on with the following purposes in view: Preparation of a catalogue of doublets and triplets; comparison with laboratory results, measurement of field strength in umbra and penumbra as a function of the diameter and the age of the spot; determination of the polarity of spots in the northern and southern hemispheres, and of different spots in a group, as related to the curvature and structure of *Hα* flocculi; determination of the proportion of longitudinal and transverse light in the sun-spot lines, and of the inclination of the axis of the electric vortex; study of the rotation of the plane of polarization in spots, and of methods of eliminating the polarization effects of the telescope and spectrograph.

The continuation of the study of the Zeeman effect in sun-spots and the knowledge that many of the lines affected in spots are most complicated in structure and require very powerful spectroscopic apparatus for complete resolution has made it desirable to revise to some extent the general catalogue of the spot-spectrum according to the results obtained with the spectrograph of the 150-foot tower telescope now under construction. Accordingly definitive publication of the catalogue is being delayed for this reason. A summary of some of the more general results, however, has been published by Mr. Adams during the past year. Among the conclusions the following may be included:

(1) About 14,000 lines are contained in the catalogue, of which 11,000 have been measured and the wave-lengths determined independently.

(2) About 5,000 lines present in the spot-spectrum have been identified as due to titanium oxide. About 600 lines have been identified by Mr. Olmsted as due to calcium hydride.

(3) A detailed study of the iron lines affected in the spectrum of sun-spots and comparison with the results obtained for the same lines in laboratory spectra of the flame and center of an iron arc strengthens the view brought forward several years ago by Fowler, and by Hale and Adams, that the observed phenomena may be accounted for satisfactorily on the basis of a reduction of temperature in sun-spots. The weakening of the enhanced lines in the spectrum of sun-spots points to the same conclusion.

(4) The existence of a magnetic field in sun-spots explains in a most satisfactory way the presence of the large number of lines which are greatly widening or show doubling or tripling in the sun-spot spectrum.

The radial movement of the vapors in sun-spots, first discovered by Evershed, has been confirmed during the past year by Mr. St. John. He is continuing the investigation with the spectrograph of the 60-foot tower telescope, using an auxiliary device by means of which spectra of different portions of the spot may be brought side by side upon the photographic plate for purposes of measurement.

Investigation of Displacements of Spectrum Lines at the Sun's Limb.

An investigation of the displacements at the sun's limb of 470 selected lines has been published by Mr. Adams during the year. Some of the principal results found are as follows:

(1) The displacements are very small for certain high-level elements, such as hydrogen, sodium, magnesium, and calcium. Also for certain elements of very high atomic weight, such as lanthanum and cerium.

(2) The displacements for titanium, vanadium, and scandium are considerably smaller than those for iron and nickel.

(3) The enhanced lines as a class show decidedly larger displacements than the arc lines.

(4) The lines most strengthened at the limb usually show small displacements.

(5) The displacements in the case of calcium and titanium and probably the enhanced lines of iron appear to increase in size in direct proportion to the wave-length of the lines. In the case of nickel and the arc lines of iron the increase toward longer wave-lengths is more rapid than in direct proportion to wave-length. These differences may readily be accounted for on the basis of differences of level among the various elements.

(6) It seems probable that the greater length of the path in the lower strata of the sun's atmosphere at the limb as compared with the center, and the relatively greater pressure in these lower strata, may account in large measure for the displacements observed.

The investigation will be continued with the spectrograph of the 150-foot tower telescope.

The General Circulation of the Calcium Vapor in the Solar Atmosphere.

Mr. St. John carried out during the year an extensive investigation on the circulation of the calcium vapor in the sun's atmosphere. Some of the principal results may be summarized as follows:

(1) The calcium-vapor producing the absorption line K_3 in the solar spectrum has a descending motion over the general surface of the sun amounting to about 1.1 km. per second in the mean. The calcium vapor producing the bright line K_2 has an ascending motion of 2.0 km. per second in the mean. The motions are essentially radial in their nature.

(2) The close agreement of the wave-lengths of K_2 and K_3 at points near the pole and the equator argues strongly against the existence of currents of appreciable velocity parallel to the sun's surface.

(3) The narrowness of the absorption lines H_3 and K_3, the lower pressure suggested by the slightly shorter wave-length of K_3, the continued increase in absolute width in passing from center to limb, as well as direct observations with a radial slit, all point to a high level, small depth, and extreme tenuity for the absorbing layer.

(4) A possible cause of the high radiating power of the emitting layer may be found in its increased temperature resulting from the transformation into heat of the mechanical energy set free by the loss of velocity in the opposing upward and downward currents.

Mr. St. John is continuing the investigation, and extending it to include measures of the bright H and K lines in the spectrum of the chromosphere.

Spectroscopic Observations of the Rotation of the Sun.

No extended series of observations on the rotation of the sun has been made during the year, but occasional photographs have been taken for the purpose of detecting a possible variation in the rate of rotation. The measurement of five of these confirms the results obtained in 1908 and indicates no appreciable change in the interval.

Photographic Observations of the "Flash" Spectrum.

The photographic investigation of the "flash" spectrum begun in the early part of 1909 by Mr. Hale and Mr. Adams has been continued throughout the year. In a communication read at the Cambridge meeting of the Astronomical and Astrophysical Society of America, August 1910, some of the results obtained were summarized. Among these may be mentioned the following:

(1) About 1,200 bright lines have been photographed and their positions measured between λ 4400 and λ 6600. Of these about 97 per cent have been identified with reasonable certainty with dark lines given in Rowland's table of the solar spectrum.

(2) Double reversal seems to be practically a universal characteristic of chromospheric lines at points close to the sun's edge.

(3) There can be no systematic shift greater than 0.002 Ångström between the average of the wave-lengths of the bright lines and the corresponding dark lines in the solar spectrum.

(4) The enhanced lines are relatively very much stronger as bright lines in the chromosphere than as dark lines in the solar spectrum.

(5) Cobalt, titanium, and vanadium show the greatest number of bright lines of any of the elements in the solar spectrum except carbon.

The large image and powerful spectroscopic equipment of the 150-foot tower should be especially favorable for the continuation of this investigation.

Miscellaneous Investigations.

A self-recording declination magnetograph has been in regular operation on Mount Wilson since the spring of 1909, with the exception of a few months during the winter season. The instrument is in charge of Mr. Babcock. The chief value of the record lies in the nature of the disturbances observed near the time of transit of sun-spots across the solar meridian. The greater part of these disturbances are found to occur about 24 hours after the transit. Perhaps the best example of this kind was that accompanying the spot which crossed the solar meridian on August 9, 1909. Twenty-four hours later the magnetic declination suddenly increased 40′, remained almost stationary for several hours, and then returned to its normal value. On the following day at about the same hour the declination suddenly decreased about 25′, but did not remain displaced.

No unusual effects were noted during the proximity of Halley's comet.

By means of a Dolazalek quadrant electrometer observations were made by Mr. Babcock of the diurnal variation of the atmospheric potential preceding and during the transit of Halley's comet.

M. Henri Chrétien devoted a considerable amount of time during the earlier part of this year to a theoretical investigation of an electromagnetic theory of the law of the sun's rotation. He also did a large amount of observational work with the 5-foot spectroheliograph and the 30-foot spectrograph.

Shortly before his departure M. Chrétien spent some weeks in Pasadena and carried on investigations on the law of distribution of stars on some of Mr. Ritchey's photographs of globular star clusters. He also did considerable theoretical work on the problem of methods of increasing the field of the reflecting telescope.

THE SIXTY-INCH REFLECTOR.

The performance of the 60-inch reflector during the past year has been extremely satisfactory from the standpoint both of photographic and of visual observations. Although comparatively few nights have been devoted to visual work, the instrument has been employed most successfully by Mr. Hale and others of the staff in observations of the planets and certain star clusters and nebulæ. Visual observations were also made by many of the visiting astronomers present at the recent meeting on Mount Wilson of the International Solar Union.

A new double-slide plate-carrier of improved design was completed in the autumn of 1909. With this instrument two guiding eye-pieces are used on opposite sides of the center. In this way any slight rotation of the field can be detected immediately and corrected by rotating the bronze plate which carries the guiding eye-pieces and the plate-holder. Two fine screws with graduated heads are provided for this purpose. The eye-pieces give a magnification of about 750 diameters.

The plates used are 3.5 inches (89 mm.) square, and are sufficiently large to cover all of the field which is free from serious distortion. The plate-holder is so designed that it can be removed quickly and replaced as frequently as desired during long exposures, thus allowing of frequent refocusing by means of the knife-edge method. The position of the plate-holder is defined by small hardened-steel surfaces, so that it returns accurately to its original position. Since, as was stated in the last report, changes of focal length have been found to be due almost entirely to the expansion and contraction of the metal tube of the telescope, it is evident that no change of scale is introduced, and hence no injury to the definition of the star-images, by frequent refocusing. With this instrument Mr. Ritchey has obtained on his best negatives, taken with Seed "23" plates, perfectly round star-images 1″.03 in diameter after an exposure of 11 hours.

A number of photographs of the stars near the north pole have been secured by Mr. Fath during the year and sent to Professor Pickering for use in his determination of a scale of photographic stellar magnitudes. One of these was obtained with an exposure of 4 hours. Although the surface of the 60-inch mirror was not in the best of condition at the time this photograph was taken, in the opinion of Professor Pickering stars of about the twentieth magnitude appear upon the negative.

Stellar Photography.

Mr. Fath has taken 3 photographs of the Kapteyn selected areas during the year. Thus far a total of 33 have been obtained since the work was begun, and it should be possible to conclude this series of photographs during the coming year. Twenty-eight photographs for use in the investigation of the absorption of light in space have been secured during the year.

Parallax Investigations.

Seven complete sets of photographs for the determination of stellar parallax have been obtained by Mr. Babcock and Mr. Fath under the direction of Professor Kapteyn. Several preliminary photographs have been made with the Cassegrain combination of 100 feet equivalent focal-length. The negatives will be investigated carefully during the coming months and future parallax work with the reflector will be guided mainly by the results obtained.

Photography of Nebulæ and Star Clusters.

Mr. Ritchey has continued throughout the year his work with the 60-inch reflector on the photography of nebulæ and star clusters. Since the last annual report he has secured photographs of the following objects:

Spiral nebulæ: *Messier* 33, 51, 63, 64, 81, H. V. 24 *Comæ Berenices, Andromeda* Nebula (central part).
Planetary nebulæ: Owl Nebula, Dumb-Bell Nebula, Planetary Nebula in *Draco,* Planetary Nebula in *Hercules.*
Annular nebulæ: Ring Nebula in *Lyra,* H. IV 13.
Irregular nebulæ: *Messier* 82, *Orion* Nebula (central part), N. G. C. 6960, N. G. C. 6992, Trifid Nebula.
Globular clusters: *Messier* 3, 13, 92.

Mr. Ritchey also obtained 17 negatives of the head of Halley's comet in May and 14 negatives in June.

The exposures on the nebulæ and star-clusters have ranged from 3 minutes on the bright planetary nebulæ to 11 hours on some of the spiral nebulæ and star-clusters.

The amount of detail shown on these photographs is in many cases extraordinarily great, especially in the case of the globular star-clusters and the spiral nebulæ. A few of the conclusions drawn by Mr. Ritchey from an examination of the negatives may be summarized as follows:

(1) The globular star-clusters are found to consist of scores of thousands of stars, and their angular diameters are at least three times as great as they appear in the large refracting telescopes. A partial count by Miss Ware of the number upon an enlargement of a negative of the *Hercules* cluster up to within 2′ of the center gives 27,000 stars.

(2) The spiral nebulæ contain great numbers of star-like condensations which may possibly be stars in process of formation. In general they lie in streams which follow the convolutions of the nebulous material in which they appear.

(3) The nebulosity is in general much brighter toward the center of the nebula, becoming gradually fainter toward the extremities of the branches. In the case of the nebulous stars, however, this tendency is less marked and they are often brighter and more numerous in the intermediate region between the center and the extremities of the branches.

(4) The nebulous stars are frequently visible in the extremities of the branches beyond the point at which the nebulosity ceases to be visible. These stars frequently occur in groups. In *Messier* 33, for example, which contains over 2,400 nebulous stars, there are at least 20 such groups, each containing from 10 to 60 stars.

Photographic Photometry.

Systematic investigations in photographic photometry have been undertaken by Mr. Seares. Fifty plates of the north pole and one other specially selected region have been obtained with the 60-inch reflector, mainly with wire-gauze screens and diaphragms of various forms and sizes. Ten additional plates of the north pole have been taken with the 60-inch reflector by Mr. Seares and Mr. Fath at the request of Professor Pickering for use in the determination of the absolute magnitudes of the fainter stars of the Harvard Polar Sequence.

At present the relation between diffraction pattern and the corresponding photographic image is being studied with a view to determining the reliability of magnitudes derived through the use of diaphragms. The results thus far obtained indicate that the systematic differences between magnitude scales based on exposures with the full aperture combined with those with diaphragms of 32, 14, and 6 inches, respectively, are at least no greater than the uncertainty of the determination of the scales themselves from a single plate. Whether there exist small systematic differences at present masked by the uncertainties mentioned remains yet to be seen. As soon as it is clear that a reliable absolute photographic magnitude scale extending to the fainter stars has been established it is proposed to undertake a determination of the brightness of the stars of the Pritchard-Kapteyn regions.

Stellar Spectroscopy.

Two stellar spectrographs have been in use throughout the past year, the high-dispersion 18-foot instrument described in the last annual report and a small low-dispersion spectrograph used at the primary focus with the Newtonian combination of mirrors. The large three-prism spectrograph which has been under construction by William Gaertner & Co. is now in Pasadena, and will soon be ready for use. It will be employed with a Cassegrain combination of 80 feet equivalent focal-length.

The observations with the 18-foot spectrograph have been carried on by Mr. Hale, Mr. Adams, and Mr. Babcock, and spectra of the following stars have been obtained: *α Orionis*, *β Orionis*, *Sirius*, *Procyon*, *Arcturus*, and *Antares*. The photographs in the cases of *Sirius* and *Arcturus* cover the

entire visible spectrum with the exception of a part of the violet. The linear scale of the spectra at λ 4300 is 1 mm. = 1.4 Ångström.

The results of an investigation of the spectra of *Sirius*, *Procyon*, and *Arcturus* are contained in a communication by Mr. Adams read at the Cambridge meeting of the Astronomical and Astrophysical Society of America in August 1910. The principal results found are as follows:

(1) The enhanced lines in the spectra of *Sirius* and *Procyon* are displaced toward the red relative to the arc lines. In the case of *Sirius* this displacement amounts to 0.014 Ångström, or 0.90 km. if measured as radial velocity. In the case of *Procyon*, 0.009 Ångström, or 0.58 km., as radial velocity. The displacement of the enhanced lines in *Arcturus* is so small as to be negligible.

(2) If we may assume, as seems probable from the investigations of Mr. Gale on the spectrum of the spark under pressure, that the enhanced lines are shifted on an average 50 per cent more than the arc lines by pressure, these results furnish us with the means of estimating the pressures in the reversing layers of these two stars. For *Sirius* the pressure would be 12 atmospheres greater than in the sun's reversing layer, and in *Procyon* 7 atmospheres greater. These values are in harmony with our general knowledge concerning the physical conditions of these stars.

(3) In the case of *Arcturus* the lines of different elements are displaced by different amounts, the lines of iron being displaced toward the red with reference to the lines of all the other elements investigated. Hydrogen, calcium, and magnesium show the largest differences from iron, and in general the elements behave in almost exactly the same way that they do at the sun's limb.

(4) It seems probable from these results that *Arcturus* is a star with a comparatively shallow reversing layer, and that within this layer the general arrangement of the gases is similar to that in the sun. The high-level gases accordingly would be subject to less pressure than those lying at a lower level, and the lines of the latter would be displaced toward the red relative to the lines of the higher elements.

It has been necessary during the past year to use a 64° prism of comparatively small aperture with the 18-foot spectrograph. We have, however, placed an order with European glass manufacturers for a block of glass sufficiently large to provide a prism which will utilize the full beam of light coming from the telescope. It will then be possible to investigate the spectra of several additional stars with this powerful instrument.

The low-dispersion spectrograph used at the principal focus of the 60-inch reflector was planned originally for use with a multiple-slit device of Mr. Hale's design with the object of obtaining the spectra of several stars at the same time. A test of the short-focus lenses employed in the instrument soon showed, however, that the curvature of the field was too great to allow of this, and accordingly we have been using it during the past year as an ordinary compound-slit spectrograph for photographing the spectra of

SPIRAL NEBULA *Messier 51 Canum Venaticorum.*

Photographed with 60-Inch Reflector, on Seed "23" plate, February 7 and 8, 1910. Exposure $3^h\ 55^m$. Enlargement from negative 6.4 diameters. Scale: 1 mm = 4″.2.

single stars. We hope to be able within a short time to secure lenses which will give a much more uniform field, and to take up again the experiments with the multiple-slit device.

Since September 1909 Mr. Adams and Mr. Babcock have obtained about 460 photographs of spectra of 128 stars with this spectrograph. The great majority of the negatives are of stars between the fifth and eighth magnitudes on the visual scale, and they have been used both for the purpose of classification of spectral type and for the determination of radial velocity. The stars observed are as follows: Kapteyn selected areas, 15; stars with known parallaxes, 98; *Scorpius* group of *Orion* type, 10; miscellaneous stars, 5. Almost all of the stars with known parallaxes have a type of spectrum resembling that of the sun.

Three spectra of Halley's comet in the more refrangible part of the spectrum were obtained before its transit in May.

The exposure-times with this spectrograph under moderately good conditions are about as follows for stars of the solar type of spectrum: for stars of visual magnitude 6.0, 12 minutes; of visual magnitude 7.0, 30 minutes; of visual magnitude 8.0, 70 minutes. These results refer to the region of the spectrum between λ 4000 and λ 4400. Spectra of Groombridge 1830, visual magnitude 6.46, have been obtained in 15 minutes under good conditions.

The measurement and reduction of a large number of these photographs has been completed by Mr. Adams, and Miss Lasby and Miss Waterman of the Computing Division. Miss Ware has also measured some of the negatives. Where possible series of measures by two observers have been made in order to reduce the accidental and personal errors inherent in this class of work. Miss Waterman has carried on the greater part of the classification of the spectra.

Although, of course, the determinations of radial velocity with this instrument are much inferior in accuracy to those made with powerful three-prism spectrographs, the results obtained are satisfactory. The probable error of a single line on a photograph of the spectrum of a star of the solar type is about 3 km., or about 1 km. for the mean of the plate when 10 lines are measured. The instrument, accordingly, provides the means of obtaining with a fair degree of precision the radial velocities of stars to about the ninth magniture on the visual scale.

Photographic Investigations of the Spectra of Globular Star-Clusters and Spiral Nebulæ.

In order to provide for work on very faint objects we have adapted the low-dispersion spectrograph for use with a 30° light flint-glass prism and a special lens, kindly loaned to us by the Yerkes Observatory, of 4 inches aperture and 7.2 inches focal length. Mr. Fath has employed this instrument during the past year and has obtained photographs of the spectra of the following objects:

Globular star-clusters: N. G. C. 5024, 5272, 6205, 6229, 6341, 6656, 6779, 6934, 7078.
Spiral nebulæ: N. G. C. 650–1, 4725, 4736, 7331.

The exposures on these objects have ranged from 3.5 to 16 hours.

From an examination of the negatives Mr. Fath concludes that essentially all of the globular star clusters photographed are approximately of the F type of spectrum on the Harvard system of classification, while the spiral nebulæ are of the G type. A few of the photographs are under-exposed, and it is possible that these results may be modified somewhat when more spectra are available. The spectrum of N. G. C. 650–1 shows 7 bright lines coincident with those found in the spectra of gaseous nebulæ, and it is possible that this object is a transition type between gaseous and spiral nebulæ.

Professor Kapteyn's Investigations.

A considerable portion of the time of Professor Kapteyn this year was devoted to the working out of a part of the program of the 60-inch reflector. Last year a series of photographs of the spectra of spiral nebulæ and star-clusters was undertaken. Since these objects are, as a rule, so faint that spectra can be obtained only of the brighter ones, and even then with low dispersion and with exposures which extend over a whole night or even two nights, especial attention has been given to the question in what way these laborious observations can be made useful in the solution of the fundamental problem whether there is an appreciable selective absorption of the light of the stars in its passage through space. For this purpose a number of observations have been added to the program of the reflector.

With the aid of Mr. Seares a program has also been worked out for the photographic determination of standards of magnitude for stars of every degree of brightness down to the faintest stars that can be obtained with a moderate exposure with the 60-inch reflector. Several observatories are already devoting much labor to this problem, and the great light-gathering power of the Mount Wilson reflector makes it particularly desirable that this Observatory should take part in the work, not only in order to aid in establishing a scale of absolute magnitudes, but also in order to extend the scale to include fainter stars than could be reached at most other observatories.

The main part of Professor Kapteyn's work, however, has been devoted to an investigation of two very extensive systems of stars of the *Orion* type of spectrum. These systems have already been shown to include probably more than half of the stars known to belong to this spectral type. It seems probable that further investigations will lead to the conclusion that these two systems are identical with two main star-streams, in which case the movement of these streams, as shown by the *Orion* stars, would be seen in its "purest" or least perturbed state, owing to the vast distance of stars having this type of spectrum. However this may be, there seems to be little doubt that as soon as a sufficient number of radial velocities are available the nature of these systems will allow us to derive the individual distances of all of the members of the groups of stars, and therefore of at least half

of the stars known to belong to the *Orion* type. This fact in itself seems to furnish sufficient reason for the inclusion of all of the *Orion* stars not under observation elsewhere, for which we have accurate determinations of the proper motion, in the radial velocity program of the 60-inch reflector. The values of the radial velocities will be used not only in the determination of the distances of the stars, but also to complete the data necessary for an accurate computation of the elements of the star systems. The faintest of these stars will be observed with the low-dispersion spectrograph; but higher dispersion can probably be used to advantage on the great majority, and for this purpose the large three-prism spectrograph will be employed.

PHYSICAL LABORATORY.

The work in the physical laboratory in Pasadena has been chiefly a continuation of the investigations in progress last year, the main lines of work being the study of the effect of a magnetic field upon the light producing the spectrum-lines, carried on by Mr. King and Mr. Babcock; electric-furnace investigations by Mr. King, and a study of the influence of pressure upon spark spectra by Mr. Gale.

The purpose of the magnetic field work has been to make a study of the Zeeman effect for a number of elements whose lines are prominent in sun-spot spectra. These spectra are photographed with high dispersion and a field of 16,000 to 20,000 gausses through the range from λ 3700 to λ 6700. The aim has been to tabulate the material in as convenient a form as possible for purposes of comparison with sun-spot spectra and for general physical work. The character of the separation produced by the magnetic field has been determined for each line in so far as the strength of field available has permitted. To do this, separate photographs are taken of the Zeeman components produced by light vibrations respectively perpendicular and parallel to the direction of magnetic force. The measurement of the separation of the components into which a single line is resolved, frequently several in number, has given a large quantity of material for direct comparison with lines showing separations in sun-spot spectra. In this way the character and strength of the magnetic field present in different sun-spots and in different regions of the same spot can be studied most effectively. Furthermore, the measurement in the laboratory of the separations of lines under a constant field, taken through a wide range of wave-length, shows in how far these separations are multiples of a fundamental interval, and how the average separation changes with wave-length.

The results of the detailed study of iron and titanium are fully worked out and will be published during the autumn. The investigation of the spectra of chromium, vanadium, and nickel along similar lines is in progress.

A comparison by Mr. King of the Zeeman separations for the lines of iron, chromium, and titanium, with the displacements of the same lines under

pressure as given by Humphreys and Duffield, indicates that there is no very direct relationship, since there are many lines affected in very different degrees by the two influences. A statistical treatment of a large number of lines, however, shows that in general there is a fair agreement between the order of magnitude of separation and displacement, pointing to the conclusion that the physical bases of the two phenomena, if not the same, are at least closely related.

The changes in spectra with varying temperature of the radiating vapor have been studied by means of the electric furnace according to the plan described in the preceding report. A classification is thus made of the lines of any element based on their response to change of temperature in the source, and we obtain for any line which is found in the furnace-spectrum not only the approximate temperature at which it appears but the rate at which the line changes in intensity with increase of temperature. It is found that in the case of some substances almost the entire arc spectrum can be obtained at the higher temperatures of the furnace. Other elements show many strong arc lines which are absent in the furnace, a fact which may be explained usually by their appearance and behavior in the arc. Several minor alterations in connection with the furnace have given greater efficiency and better results, and the material for the study of the spectra of a number of elements having many lines is nearly complete.

Mr. Gale spent the months of March, April, and May in Pasadena engaged in an investigation of the spectrum of the electric spark under pressure. Reference has already been made to some of the results found in the course of his work, but on account of their important applications to certain astrophysical problems they may well be repeated at this point.

(1) The enhanced lines remain bright under pressures at which the great majority of the other lines are reversed. A probable explanation of the intensity and persistence of the enhanced lines in the spectrum of the sun's chromosphere is afforded by these observations. Since the pressures employed in the laboratory investigations were nearly the same as those present in the sun's reversing layer, it is evident that at the sun's edge we should expect the enhanced lines to appear bright when the majority of the arc lines are still dark. This is in agreement with observations. Similarly the arc lines which remain bright under pressure are in almost all cases prominent in the spectrum of the chromosphere.

(2) The enhanced lines are displaced more than the arc lines at the same pressures. In an investigation of the spectra of the sun's limb it was found that the enhanced lines are displaced more than the other lines, and a similar effect is present in the spectra of the stars *Sirius* and *Procyon*. The laboratory results, accordingly, appear to furnish us with a means of determining quantitatively the pressures in the atmospheres of certain stars.

A short investigation has been made by Mr. King of the relative wavelengths of lines given by the arc and by the spark. The long-focus Littrow spectrograph, giving high dispersion with freedom from astigmatism, com-

bined with the powerful transformer spark, provides the means of getting more definite data on the subject than has been possible with most other apparatus. The experiments, so far as they have progressed, show that the spark, with a proper adjustment of circuit conditions, gives in most cases lines which would be measured as having a wave-length greater than the arc lines, though the photographs also show to what extent unsymmetrical widening may explain the effect. The conditions requisite for this apparent difference in wave-length appear to be confined to the central part of the spark, the outer portions giving lines coinciding with the arc lines.

The instrumental equipment of the laboratory has received a number of additions during the year, chief among which are the following: an 8-inch plane grating by Michelson, which has proved very efficient when used in the spectrograph of 30 feet focal-length; a Rowland concave grating of 1 meter radius to be mounted for use in low-dispersion work; a Gaertner comparator; a D'Arsonval ballistic galvanometer; standards of resistance, electromotive force, capacity, and self-induction; several voltmeters and ammeters of different ranges; a Gaede high-vacuum pump, and a Cox mercury interrupter.

A plate condenser having a capacity of about 0.06 microfarad and capable of sustaining a 1-inch spark has been built in the laboratory.

The measurement of plates and the computations in connection with the laboratory work have been carried on for the most part by Miss Griffin of the Computing Division.

THE COMPUTING DIVISION.

The Computing Division has remained throughout the year under the charge of Mr. Seares.

Miss Burwell has been engaged in the measurement and reduction of sun-spot spectra. The discussion of the material available for the catalogue of sun-spot lines was practically finished at the time of the last report. During the year she has devoted her attention to various phases of the Zeeman effect in spot spectra. Some 60 photographs taken with and without a Nicol prism have been examined for the purpose of analyzing the character of the lines in the presence of the magnetic field, and such as are suitable for the purpose have been measured for the determination of the strength of field. The plates of various spots and spot groups have been examined for polarity. Miss Burwell has also undertaken a detailed comparison of the lines of the spectrum of *Arcturus* with those of the spot-spectrum, using the photographs obtained with the 18-foot stellar spectrograph.

Miss Griffin, since her appointment on February 1, has devoted the greater part of her time to the measurement and reduction of laboratory spectrum photographs, about 100 in all, relating to the Zeeman effect. She has also made measures of brightness on several plates taken for photometric purposes, and has determined the screw errors of three small comparators used in the measurement of spectra.

Miss Lasby has continued the measurement and reduction of the photographs of stellar spectra taken with high dispersion. Of these 26 have been reduced and the results discussed both with respect to the peculiarities exhibited by the arc and the enhanced lines in certain stars and with respect to the systematic deviations shown by the lines of different elements. Miss Lasby has also measured and reduced 215 low-dispersion stellar spectrum plates obtained with the one-prism spectrograph in the principal focus of the 60-inch reflector, and a number of solar rotation, chromosphere, and laboratory photographs.

Miss Smith has continued, as in the past, the measurement of the calcium flocculi and prominence areas, and has reduced during the year 148 calcium and 150 prominence plates by the weight method explained in the last report. All of the plates of these series are completely reduced to February 1, 1910, and the final curves showing the fluctuation of the calcium flocculi and prominence areas have been constructed up to November 4, 1909. Miss Smith has also begun, under the direction of Mr. Hale, an extensive examination and comparison of direct photographs of the sun with H_2 and $H\alpha$ spectroheliograms for the purpose of obtaining more definite information concerning sun-spot structure and related phenomena. To avoid the inconvenience involved in handling large numbers of plates, Miss Smith has made and used for the comparison paper prints which have been collected in volumes, each volume showing the complete history, so far as recorded, of each of the spots or spot groups studied. Fifteen of these, comprising some 700 prints, are complete at present, and the tabulation of the data resulting from this comparison has been finished.

The prints used in this investigation have proved so convenient for rapid examination and comparison that it is proposed in the future to make similar prints for all direct photographs and spectroheliograms as they are obtained.

Miss Ware has been engaged mainly in the measurement of solar and stellar spectra. The stellar-spectrum work has included the measurement and reduction of several high-dispersion photographs as well as a considerable number of the low-dispersion plates of the fainter stars. Recently she has measured a large number of solar spectrum negatives for the determination of the absolute wave-lengths of the H and K lines at various points on the solar disk and in the chromosphere. The work forms part of an extensive investigation by Mr. St. John of the circulation of the calcium vapor in the neighborhood of spots and spot-groups, as well as in the general solar atmosphere. Miss Ware has also carried on the difficult work of determining the number of stars present upon the photograph of one of the globular star clusters.

Miss Waterman's time has been devoted mainly to the study of stellar spectra, some 250 low-dispersion plates having been measured and reduced, and over 400 classified according to type of spectrum. In addition she has measured some laboratory photographs of spectra taken under pressure, and

has given a large amount of time to computations connected with the investigation of the solar rotation.

Miss Wickham continued, up to the time of her resignation on February 1, her measures of laboratory photographs taken for the investigation of the Zeeman effect. She also measured a considerable number of chromosphere plates and one of the high-dispersion stellar spectrum negatives.

Although the books and pamphlets of the library had been roughly classified, no attempt at cataloguing was made until the appointment of Miss Haines on March 1. Since then the classification has been completely revised and all of the bound volumes have been catalogued. The loss of books as a result of the burning of the quarters was serious, but we have succeeded in replacing most of those burned. The accessions during the year through purchase amount to about 125 volumes, while in addition the value of the collection has been greatly enhanced through the gift of a large number of volumes from various institutions and societies. At present the bound volumes in the collection number 1,451.

CONSTRUCTION DIVISION.

All of the construction work of the year has been under the general supervision of the Director, with Mr. Ayers in immediate charge of the work in the instrument shop and Mr. Jones in immediate charge of the work on Mount Wilson. The difficult work involved in the details of the design of the instruments built during the year has been under the immediate charge of Mr. Pease. Mr. Ritchey has remained in charge of the design of the 100-inch telescope.

Among the instruments constructed in the instrument shop during the past year the most important are the following:

The new double-slide plate-carrier for the 60-inch reflector.

The cœlostat, second mirror support, and lens mounting for the 150-foot tower telescope, including tracks, and slow-motion and focusing attachments.

The larger portions of the 75-foot spectrograph and spectroheliograph to be used with the 150-foot tower telescope; also the slits, with their supports and various auxiliary attachments.

Additional parts of the 100-inch grinding-machine, which complete its construction.

In addition a large number of smaller pieces of apparatus have been built, and minor repairs made on existing instruments.

THE ONE HUNDRED AND FIFTY FOOT TOWER TELESCOPE.

The erection of the tower telescope was begun last year and two of the lower sections were completed before the opening of the rainy season put an end to the construction work. The large pit, 78 feet deep, beneath the tower was also completed and thoroughly dried during the winter by artificial means. Erection work was begun again in March of this year and continued until September. With the exception of the spectroscopic equipment still under construction in the Pasadena instrument shop, the tower

telescope is now essentially complete. The concrete laboratory at its base has also been finished and the mirrors and 150-foot focus lens are installed.

The general features of the telescope were described in the last report. The erection of the two towers, one inclosed within the members of the other, has been carried out most successfully by Mr. Jones. The dome which covers the instruments at the top of the tower consists of two approximately hemispherical sections of slightly different radius, one of which may be rotated within the other. This form of construction has the marked advantage of affording a very large opening and thus promoting the free circulation of air about the mirrors. A square tube 5.5 feet in size, built of angle iron and lined with sheet iron, extends the full height of the tower, inclosing the beam of light from the lens and protecting it from disturbing air-currents. To prevent heating, the outside of the tube is covered with canvas louvers of a form similar to those used on the Snow telescope house. The dome is supported by the outer tower, and the tube jointly by the outer tower and the concrete roof of the laboratory.

The mirrors which have been figured in the Pasadena optical shop are about 12 inches thick and similar to those which have proved so successful in use with the 60-foot tower telescope. To prevent distortion due to heating of the edges, the sides of the mirrors are incased in closely fitting water-jackets through which a stream of water may be kept circulating. The lens now in use is 12 inches in diameter and of the triple construction designed by Hastings to reduce the effect of chromatic aberration. The 75-foot focus lens for use in the spectrograph is of the same form. Both lenses will be given a careful test during the next few months.

The few preliminary trials thus far made with the tower telescope indicate that it should prove most successful in regular operation. The 17-inch image of the sun shows excellent definition on days when the observing conditions are good, and there appears to be an entire absence of vibration due to shaking of the tower by the wind.

THE MONASTERY.

On December 13, 1909, a fire caused by an overheated range entirely destroyed the Monastery. A considerable number of valuable books were burned, but fortunately little was lost that can not be replaced readily. As soon as the rainy season was over the work of rebuilding was commenced, and is now completed. The present building is of reinforced concrete throughout and follows closely the general design of the former Monastery. A few additional rooms have been provided and more convenient heating and water systems installed. The Observatory is indebted to the Carnegie Institution of Washington for a special appropriation by means of which it was enabled to reconstruct so promptly and in such a satisfactory and permanent form the building about which so large a part of the social life on Mount Wilson naturally centers.

THE ONE-HUNDRED-INCH TELESCOPE.

The details of the design of the 100-inch telescope have made excellent progress during the year under the immediate direction of Mr. Ritchey. The experience gained during the last year with the 60-inch reflecting telescope has been of the greatest value in guiding the design of the larger instrument.

As stated in the last report, the glass disk, weighing 4.5 tons, which was secured from the St. Gobain firm, contained so many flaws that it seemed inadvisable to accept it. Since this disk was made the St. Gobain firm has been continuing the attempt to secure a perfect casting. A very large furnace and melting-pot capable of holding 20 tons of material has been constructed and improved methods of annealing have been introduced. In the spring of this year a successful disk was cast, but unfortunately, owing to defects in the mold, strains were introduced in the process of annealing and the disk was broken. With the experience gained from these trials we may reasonably hope for a perfect disk before very long.

The large grinding-machine for the 100-inch disk has been completed during the year and the shaping and rough-grinding of the 60-inch plane mirror to be used in testing the larger disk has been nearly finished.

THE INTERNATIONAL SOLAR UNION MEETING.

The fourth Conference of the International Union for Cooperation in Solar Research was held on Mount Wilson during the week of August 29 to September 3, 1910. About 80 members of the Union and invited guests were present. A brief outline of the program of the Conference follows:

August 29. Inspection of the Pasadena offices, instrument and optical shops, and physical laboratory.
August 30. Journey to Mount Wilson.
August 31. (1) Opening address by Professor Hale.
(2) Report of the executive committee.
(3) Report of the committee on standards of wave-length.
At 8 p. m. Address by Mr. Abbot.
September 1. Report of the committee on the measurement of solar radiation.
Report of the committee on the investigation of the spectra of sun-spots.
Report of the committee for the organization of eclipse observations.
At 8 p. m. Address by Professor Kapteyn.
September 2.
Morning session:
Report of the committee on the determination of the solar rotation by means of the displacements of lines.
Report of the committee on work with the spectroheliograph.
Afternoon session:
Discussion of a proposal to extend the scope of the Union.
Nomination and election of committees.

Meetings of the astrographic chart committee and of the committee on the Kapteyn Selected Areas were held in connection with the Conference.

Important action was taken by the Solar Union on a number of questions connected with solar and stellar research. In particular, we may refer to the adoption of secondary standards of wave-length; the recommendation of certain instruments as standards for the measurement of radiation; the progress made toward additional cooperative work among sun-spot observers and

those working on the solar rotation, and finally, the extension of the scope of the Union so as to include general astrophysics and the appointment of a committee to consider stellar classification.

During their stay on Mount Wilson the visiting astronomers made many observations with the Snow and tower telescopes and with the 60-inch reflector.

NUTRITION LABORATORY.*

FRANCIS G. BENEDICT, DIRECTOR.

During the past year the equipment of the Nutrition Laboratory has been increased considerably by purchase, and particularly by the construction of special apparatus of our own devising. Preliminary investigations have been carried out, aiming toward the solution of some of the innumerable problems in human nutrition, and the investigations begun in previous years have been continued and the results in large measure prepared for publication.

ADDITIONS TO EQUIPMENT.

While the respiration calorimeter, as originally built at Wesleyan University, marked a great advance in the study of physiological problems dealing with the transformations of matter and energy, each year of experience suggests changes in the apparatus of practical value for increasing its efficiency or facilitating manipulation. To enable us to make such changes and improvements, a machine shop was included in the original equipment of the laboratory. Certain alterations in the interior arrangement of the building itself have also been made necessary by the demands for increased space resulting from a larger use of the apparatus.

RESPIRATION CALORIMETERS.

During the past year a third respiration calorimeter has been built and completely finished. This is somewhat larger than the calorimeters previously constructed and will accommodate a man lying down or standing upright, and will permit a subject to work upon a bicycle ergometer. The apparatus is designed for experiments of 24 or more hours' duration, and thus provides for more extended observations than are possible with either of the two calorimeters first constructed. The new calorimeter has not yet been used for experiments with man, but has been satisfactorily tested electrically and some preliminary trials have also been made by burning known amounts of alcohol inside the chamber.

During the latter part of this year the construction of a large respiration calorimeter has been begun for the purpose of studying muscular work, particularly that in which the legs are used in the motion of forward progression and up and down an inclined plane. The structural-steel framework and the copper lining or inside chamber of this respiration calorimeter have been finished, and it is expected that the entire apparatus will be completed within a year.

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* Situated at Boston, Mass. Grant No. 606. $26,378 for investigations and maintenance during 1910. (For previous reports on work in nutrition see Year Books Nos. 2–8.)

In researches with the respiration calorimeter just mentioned, it is planned to use a treadmill of unique design, on which it will be possible for the subject to walk forward at any desired rate, or even to run. The construction of this treadmill is well under way.

An important factor in the measurement of heat by the calorimeter is the physical observer's table, where all the heat-controlling appliances are installed and all temperature measurements recorded. The original table, which was more or less experimentally constructed, has been replaced by a substantial permanently constructed and wired table, which has been tested for a year.

The building of a third calorimeter made necessary the construction of a second observer's table for controlling the calorimetric features of the apparatus. From this table it is possible to control not only the new calorimeter, but also one of the calorimeters controlled from the other observer's table, *i. e.*, the bed calorimeter. It is thus practicable to make experiments with any two of the three completed calorimeters at one time. The special features of these two tables will be described in a future publication.

RECONSTRUCTION OF CHAIR CALORIMETER.

In using the chair calorimeter, which is described in Publication No. 123, experience showed that the entrance as originally placed was very inconvenient. As the opening was at the top, it was necessary for the subject to ascend a ladder, then climb over the side of the opening, and descend a small ladder to the floor of the chamber and seat himself in the chair. The method of entering the apparatus was thus very complicated, and there was danger that inexperienced subjects might strike the head on parts of the chamber or on the framework above the chamber. The opening has therefore been changed from the top to the front of the calorimeter chamber. It is fitted with two panes of plate glass which are easily manipulated and give a very satisfactory closure. This change has been of great advantage, as the subject can very easily enter the chamber and sit in the chair without great difficulty. In reconstructing the top slight alterations were made which give somewhat more space for the shoulders and head, and while the total content of the chamber has been increased but little, the advantages are considerable.

RESPIRATION APPARATUS FOR MEN.

In the last report mention was made of a respiration apparatus for the determination of the respiratory quotient and of the respiratory exchange in short periods, which had been developed and constructed in this laboratory. While a considerable number of experiments had been made with it, it was not by any means perfected in all minor details, and during the past year another apparatus has been built on exactly the same principle as the previous one. This has been constructed more substantially and more carefully finished, and a number of improvements made. The new apparatus was

completed late in the spring and has been in almost constant use since that time. It has been very satisfactory, and is much more easily manipulated than the first apparatus. A third apparatus is now in process of construction.

RESPIRATION APPARATUS FOR DOGS.

For use in an investigation in which dogs were employed for subjects, a respiration apparatus was constructed of galvanized sheet-iron with a capacity of about 1 cubic meter. The apparatus was constructed on the closed-chamber principle, and in use the animal was placed inside the chamber and analyses of the air made periodically, the rise in carbon dioxide being noted. This apparatus proved very serviceable. After the routine and method of procedure had been thoroughly established, however, it was found that the apparatus was somewhat too large for securing the most accurate results with the small dogs required for the particular research in progress. A second respiration apparatus was therefore constructed upon the same principle with a cubic content of only about one-third of a cubic meter. This apparatus has been used almost exclusively since its construction and gives perfectly satisfactory results. The chamber is in the shape of a cube, with a cover placed upon the top closed with a water-seal; on one side of the chamber is constructed a supplementary apparatus to determine the activity of the subject. The movements of the animal confined in the small cage which is fastened inside of the apparatus result in a vertical displacement of a pointer which records the variations upon smoked paper. Samples of air are periodically withdrawn and the carbon dioxide determined. Only the variations in the carbon-dioxide content have thus far been studied.

ADIABATIC CALORIMETER.

The new adiabatic calorimeter mentioned in the last report has been improved and completed, and it is now in permanent useful condition and has been in constant use during the past year. The results have been extremely satisfactory, less time being required for the determinations and its manipulation being much easier.

CHANGES IN THE CALORIMETER LABORATORY.

Much of the construction in half of the respiration calorimeter laboratory is practically completed, and instead of relaying the floor, as was originally planned, it was decided to cover the floor with linoleum. The heaviest grade of linoleum was used and cut and laid so that it would be possible, for repair work, etc., to easily uncover the troughs through which the piping runs. This floor covering has been very satisfactory.

As originally constructed, the respiration calorimeter laboratory had a head-room of about 15 feet and in some parts of the room this is not utilized. Since so large a portion of the floor space was being used for the respiration

calorimeters and accessory apparatus, it was considered advisable to increase the facilities of the laboratory by constructing a gallery upon which apparatus could be stored and which would also provide desk-room for assistants in connection with the work. Accordingly such a gallery, with stairway, has been built in the southwest corner of the laboratory, and an assistant permanently stationed there, who makes the calculations for each experiment as soon as the results are available. It has been found a very great advantage to have the work done in the calorimeter laboratory. A part of the space has also been utilized for storing apparatus, printed forms, etc., which are to be used in the laboratory, and which are thus immediately available when needed and out of the way at other times.

SPECIAL APPARATUS AND MACHINERY.

In a recent European trip several pieces of apparatus were ordered for the use of the laboratory. Among these were a Deprez-d'Arsonval galvanometer and a Sondén-Pettersson gas-analysis apparatus. Three Brunswick calculating machines were also purchased for use in calculations. For the purpose of still further increasing the efficiency of the machine-shop, a precision lathe has been added to its equipment. During the past year there has been added to the office equipment a phonograph for dictation, and much use has been made of it, especially in preparing rough drafts of material intended for publication.

COOPERATING AND VISITING INVESTIGATORS.

Dr. Elliott P. Joslin has continued his cooperation in the study of metabolism in diabetes and has offered many helpful suggestions in connection with the work. He has also had entire care of the patients, and it is almost entirely due to his enthusiastic assistance that the laboratory has been able to carry out this work.

Dr. John Homans, of the Harvard Medical School, has likewise cooperated in the investigations upon the influence of the removal of the hypophysis from small animals.

A number of foreign investigators have visited the Nutrition Laboratory during the past year, their visits varying in length from several days to two or three weeks. Among them was Prof. Otto Cohnheim, of Heidelberg, who spent two or three weeks at the laboratory and served as the subject of several experiments with the respiration apparatus and the respiration calorimeter. He also made a critical study of the respiration apparatus for men with the idea of applying the same principles to the study of the gaseous metabolism of extirpated organs. Dr. M. Hindhede, of Copenhagen, Denmark, spent about three weeks at the laboratory during the early part of the spring, and was the subject of several experiments in the respiration calorimeter dealing with the influence of food upon metabolism. Prof. Adolph Magnus-Levy, of Berlin, spent two or three days at the laboratory, and made a short study of the methods employed in the investigations on metabolism

in diabetes. He read in manuscript the entire report on this investigation which has recently been published (Publication No. 136), and offered a number of suggestions for use in further investigation on the subject.

STAFF NOTES.

In conformity with a plan outlined at the inception of the laboratory, the Director took an extended tour in Europe (during the spring and early summer), visiting different laboratories and investigators who were interested in researches in nutrition and allied subjects. While on a previous trip, three years ago, his main object was the inspection of laboratory construction and equipment, with special reference to apparatus; on this tour he was able to spend much more time in the discussion of experiments, plans, and problems that might be advantageously studied, with special reference to clinical problems, particularly diabetes. The cordiality with which he was received in all hospitals, laboratories, and clinics, and the great interest exhibited by the different investigators in the researches being carried on by the Carnegie Institution of Washington in general, and by the Nutrition Laboratory in particular, make it seem all the more desirable to continue these periodic European tours and thus keep in close touch with foreign investigators. As many of the American scientific investigators visit the laboratory, it enables the observers to keep in touch with the scientific work and workers in this country. It is very gratifying to see the number of foreign investigators who are now exhibiting an interest in the Nutrition Laboratory, both by correspondence and by personal visit.

During the Director's absence Mr. T. M. Carpenter had the entire charge of the laboratory as acting Director, and, with the necessity for the presentation of results and the writing of reports of major investigations, it has become more and more necessary to readjust the administration of the laboratory so as to make more advantageous use of Mr. Carpenter's excellent administrative ability.

When the laboratory was first established, although provision was made for subsequent extension of chemical research, as distinguished from the calorimetric investigations, it was deemed important to first perfect the calorimeters, which made it possible for researches on the energy transformations of man to be carried out in this laboratory as nowhere else. This elaboration of calorimetric apparatus was continued to the neglect of the development of the chemical side, but, with the satisfactory completion of three calorimeters, chemical research may now be advantageously undertaken. We have been extremely fortunate in inducing Dr. A. W. Peters, who has been associated with Prof. Otto Folin, of the Harvard Medical School, for the past two years, to join our staff. Dr. Peters will for the most part confine himself to such problems of nutrition as are of a purely chemical nature.

The complicated electrical devices used in connection with the calorimeters and in many projected investigations necessitated the presence of an electri-

cal expert, and Mr. E. P. Slack, for two years an assistant in the electrical laboratory of the Massachusetts Institute of Technology, has been associated with the laboratory for the past year. During this time he has been occupied in developing accessory apparatus for use with the respiration calorimeter, and more particularly upon a development of the thermo-electrical method for determining body-temperature.

The office work and administration of the laboratory have been so modified as to utilize to much better advantage the editorial skill of Miss A. N. Darling, whose long association with the Nutrition Laboratory and with the investigations in Middletown, Connecticut, make her peculiarly fitted for this kind of work.

INVESTIGATIONS NOW IN PROGRESS.

METABOLISM IN DIABETES.

The investigation of metabolism during diabetes continues to be the most important single investigation now in progress in the laboratory. Cooperating with Dr. Elliott P. Joslin, a number of experiments have been made, some with the subjects of previous years and some with new subjects. The abnormal metabolism noted in many of the older subjects was such as to make it advisable to secure as many cases of severe diabetes as possible. The gravity of the cases may be inferred from the fact that out of the 13 cases studied, 9 have already died, for the most part in coma. Although it was found in the two previous years that the ingestion of food other than protein did not result in any material alteration in the metabolism of diabetics, the plan of studying these cases 12 hours after the last meal is still for the most part adhered to. The whole equipment of the laboratory apparatus is used in these investigations—the bed and chair calorimeter as well as the respiration apparatus. Incidentally, observations with regard to pulse-rate, respiration-rate, and body activity are made simultaneously. The results of the first two years' work on this subject are most gratifying and the plan of a definite, long-continued research leading toward a fundamental knowledge of this disease is fully substantiated by the results thus far. It has been made obvious that investigations including but one or two cases are wholly inadequate for any fundamental knowledge of this obscure disturbance of metabolism. During a recent tour in Europe the Director was in touch with all the foremost clinicians, and the policy of the Nutrition Laboratory in attacking the problem in this way was thoroughly approved by all.

INFLUENCE OF INGESTION OF FOOD ON METABOLISM.

In connection with the investigations carried out at Wesleyan University, Middletown, Connecticut, approximately 100 experiments were made to study the influence on metabolism of the ingestion of food. In collecting the results of these experiments for publication it was found necessary to supplement them by further research on the subject, and accordingly, as often

as pressure of other work permitted, experiments of 4, 6, or 8 hours were made. In all, some 33 of these experiments were carried out. The routine and general plan of the experiments were the same as in the experiments previously conducted at Wesleyan University, but, as the chair calorimeter was used for these later studies, a higher degree of accuracy was obtained than was possible in the Middletown investigations. The results of both series of experiments will be published as soon as practicable.

METABOLISM OF WOMEN.

Since so large a proportion of the experiments made in the past have been with men, it was considered of value to make a special study of the normal metabolism of women. For this investigation both calorimeters were used, the experiments in all cases being made 12 hours after the ingestion of food. Most of the subjects were young. The experiments (27 in all) were preliminary in character and the investigations will be continued further as opportunity offers.

INFLUENCE ON METABOLISM OF THE REMOVAL OF THE HYPOPHYSIS FROM ANIMALS.

Much interest has been exhibited in recent years in the study of the effect upon metabolism of the ductless glands in various parts of the body. In this connection considerable study has been made of the effect of the removal of the hypophysis from small animals, and an investigation of this subject has been begun in this laboratory by Dr. John Homans, of the Harvard Medical School. Dr. Homans has used in his experiments two or three very young dogs, and, with the respiration apparatus for dogs previously mentioned, has studied the influence of the removal of the hypophysis upon the total metabolism as measured by the carbon dioxide. He first studied the carbon-dioxide output periodically in young dogs, and, after he had established the control, he removed the hypophysis, in part or wholly, from the animal. Shortly after their recovery from the operation the dogs were placed in the respiration chamber and the metabolism again studied. In all of the experiments careful observations were made of the muscular activity and of the pulse-rate. The urine was also collected daily during the whole period of the experiment and analyzed for nitrogen. With one animal, after the greater portion of the hypophysis had been removed, the effect of an injection of an extract of the gland was studied and preliminary data have been obtained upon this subject.

COMPARISON OF METHODS FOR STUDYING THE RESPIRATORY EXCHANGE.

In the plans for investigations originally made for this laboratory, a study of the different methods employed for determining the respiratory exchange was included, and accordingly several types of apparatus for studying the respiratory exchange were made a part of the initial equipment. Among these were the Zuntz apparatus and the Chauveau and Tissot spirometer. In addition, an apparatus was devised and constructed in this laboratory

which gives very accurate determinations of the respiratory exchange in short periods. Utilizing the experience he obtained in both the French and German laboratories, Mr. T. M. Carpenter has during the past year begun this comparative study of the methods of determining the respiratory exchange, using these three types of apparatus. A preliminary study of the respiratory exchange after a short fast has already been made and the investigation will be carried further. These results will also be compared with the results obtained with the bed calorimeter, which gives accurate determinations of the respiratory exchange in periods 1 hour in length. A comparison of these methods is deemed of vital importance by many foreign investigators.

INFLUENCE OF OXYGEN-RICH MIXTURES UPON THE RESPIRATORY EXCHANGE.

The respiration apparatus, of which mention has already been made, offers a peculiarly advantageous opportunity for the study of the influence of oxygen-rich mixtures upon the respiratory exchange, and accordingly experiments were carried out along this line during the earlier part of the year. Using normal atmospheric air, a large number of experiments were made in which the respiratory exchange was determined 12 hours or more after the last meal. The percentage of oxygen in the apparatus was then arbitrarily increased and the respiratory exchange again determined under identically the same conditions and on the same day, except that the air used was rich in oxygen, 90 per cent or more. Five or six different individuals have been used as subjects, with different percentages of oxygen, and it is expected that the results of these experiments will throw very definite light upon the question of the oxygen absorption with oxygen-rich mixtures. The work has been carried out by Mr. H. L. Higgins of the laboratory staff.

THE INFLUENCE OF THE PRECEDING DIET UPON THE RESPIRATORY EXCHANGE.

In the last report reference was made to a study which had been begun on the influence of the previous diet upon the respiratory quotient. It was expected at that time that the results of this study would soon be published, but it was deemed advisable to continue the work further. This investigation has also been supplemented by noting the effect of diet upon fasting value in connection with the investigation upon the effect of oxygen-rich mixtures. Considerable data have been added in this manner and the whole material is now being prepared for publication.

TOPOGRAPHICAL STUDY OF BODY-TEMPERATURE.

The desirability of a topographical study of body-temperatures has been increasingly apparent in the work of the laboratory and plans for a thorough investigation of the subject have long been made. Mr. Edgar P. Slack has been at work during the past year compiling material upon this topic and constructing thermometers and accessory apparatus to be used in connection with the research. In the investigations a simultaneous study will be made of the temperature of the different portions of the body, such as the mouth, stomach, colon, vagina, and axilla, and upon various parts of the body-

surface. It is hoped by this means to obtain some information upon the question as to whether a change in temperature in one portion of the body is accompanied by a similar change in another portion, a question of fundamental importance in experiments on heat production.

HEAT OF COMBUSTION OF ORGANIC COMPOUNDS.

Considerable attention has been given during the past year to the determination of the heat of combustion of a number of organic compounds, particularly those which are very important in investigations in physiological chemistry. The adiabatic bomb calorimeter previously mentioned was used for this work and the most time was given to the determinations of the heat of combustion of ethyl alcohol. Ordinary alcohol was used, *i. e.*, about 90 per cent, in gelatine capsules, and also in glass bulbs according to the method described by Richards. This alcohol has also been diluted in varying proportions, and accurate determinations made of the heat of combustion. In addition to the work on alcohol, some preliminary determinations have been made of the heat of combustion of acetone, lactic acid, and some foods. It is expected to continue this work in connection with other work in the laboratory.

ANALYSES OF DIABETIC FOODS.

In connection with the study of diabetes carried on in cooperation with Dr. E. P. Joslin, a number of diabetic foods, so-called, have been collected and analyzed. Many of these foods are especially advertised as being excellent for the use of diabetics, and accordingly particular attention has been paid to the determination of the total carbohydrate content. A great variety of foods was analyzed, not only breads, but also sugarless milk, sugarless jelly, chocolate, vegetables of various kinds, and other materials recommended for diabetics. The analyses of these foods have proved of great value in connection with the treatment of diabetics, as such foods were sometimes found to contain more carbohydrates than stated. They could thus be eliminated from the diet of a patient and the ingestion of carbohydrate properly controlled.

NUTRITIVE VALUE OF SERVINGS OF FOOD.

The average individual has little, if any, conception of the amount of nutriment in food, and when we attempt to estimate the energy in a single meal, or, indeed, in a single helping of food, we find that it is very difficult to obtain any very accurate idea of the amount. Most people, including many considered to be experts, when given the number of materials in a meal and an approximate idea of the size of the helpings, are unable to tell how much energy the materials should supply. When the weight and heat of combustion of a material are known, the amount of energy can be calculated very closely, but very few people are in a position to weigh every helping during the meal or to know the heat of combustion of the different materials used or the amount of protein contained in them.

Recognizing this lack of knowledge, an investigation has been begun in this laboratory in the hope of supplying such information. Ordinary servings of food have been collected and weighed and a sample of the serving saved for analysis. At some future time determinations will be made on these samples of the heat of combustion, the nitrogen, and the carbohydrates. It is hoped in this way to collect enough data so that with a knowledge of the materials included in a meal and an idea of the size of the helpings, the amount of energy in any given meal may be calculated, at least approximately. In addition to the collection of samples for analysis, the compilation of published analyses of cooked foods has been begun and will be continued.

ANALYSES OF OUTDOOR AIR.

The analyses of the outdoor air begun last year have been continued. These have been made almost daily by means of the Sondén-Pettersson gas-analysis apparatus, with which very accurate determinations of carbon dioxide, oxygen, and nitrogen can be made. Occasionally variations have been found in the oxygen content of the air which are not accompanied by similar variations in the carbon-dioxide content. No cause has thus far been ascertained for this variation, and it is planned to make an even more thorough study of such variations in the coming year, supplementing the analyses with very accurate controls to make sure that the differences are not due to variations in the apparatus. The significance of oxygen in respiratory processes and the almost universal use of the oxygen content of the air as a constant fully justify the continuance of this most interesting meteorological study.

PUBLICATIONS.

The following publications have been prepared and issued during the past year:

(1) A comparison of the direct and indirect determination of oxygen consumed by man. Francis G. Benedict. Amer. Jour. Physiol., 26, p. 15. 1910.

The great importance of knowing accurately the amount of oxygen consumed by man has led to many attempts to make this determination indirectly. By means of simple forms of respiration apparatus it is possible to determine the carbon dioxide eliminated and the water vaporized. If accurate records of the body-weight can be obtained, the oxygen consumed may also be computed by the simple formula $a = b + c - d$, in which a is the weight of the oxygen, b the weight of carbon dioxide, c the weight of water vaporized, and d the loss in body-weight of the subject. While it is relatively easy to determine with considerable accuracy the carbon dioxide eliminated, it is extremely difficult to determine the water vaporized, and the errors incidental to the determination of changes in body-weight are ordinarily so great that it is practically impossible to use this method for the accurate determination of oxygen. With the new respiration calorimeters at the Nutrition Laboratory the determination of all the grosser factors of metabolism—*i. e.*, carbon-dioxide production, water-vapor elimination, oxygen absorption, and, indeed, heat elimination—was extremely satisfactory. With the installation of a special balance, the changes in body-weight could be

recorded to within a few tenths of a gram. Inasmuch as this apparatus was provided with a method for determining oxygen directly, experiments were made for comparing the direct and indirect determinations. The experiments were all made with men sitting quietly in a chair suspended on a balance inside the respiration chamber. A sample experiment is given in the table herewith:

Comparison of the Direct and Indirect Determinations of Oxygen.

[Metabolism Experiment, January 31, 1910.]

Period.	(*a*) Carbon dioxide eliminated.	(*b*) Water vaporized.	(*c*) Loss in body-weight (calculated to 60 min.).	(*d*) Oxygen consumed (indirect determination). $(a+b)-c$.	(*e*) Oxygen consumed (direct determination).	(*f*) Ratio of indirect determination to direct determination. $(d \div e.)$
	grams.	*grams.*	*grams.*	*grams.*	*grams.*	*per cent.*
First	27.2	33.7	38.1	22.8	23.4	97.4
Second	32.3	33.9	42.4	23.8	25.0	95.2
Third	34.8	33.2	41.3	26.7	25.4	105.1
Fourth	31.0	34 4	39.0	26.4	26.0	101.5
Fifth	25.5	31.2	35.7	21.0	20.9	100.5
Sixth	26.3	29.4	35.0	20.7	22.0	94.1
Total	177.1	195.8	231.5	141.4	142.7	99.1

The result of the experiment showed that while the indirect method with extraordinary precautions could be used, the indications are that the errors involved in the indirect determination of oxygen are such as to preclude its use under the conditions that ordinarily obtain even in the most perfect forms of respiration apparatus, and the accurate determination of the oxygen consumption of man is practicable only by the use of the direct method.

(2) Control tests of a respiration calorimeter. Francis G. Benedict, J. A. Riche, and L. E. Emmes. Amer. Jour. Physiol., 26, p. 1. 1910.

Two of the respiration calorimeters now in use in the Nutrition Laboratory were subjected to the most rigid control tests to show their capability for determining the four important factors of metabolism in man, namely, carbon-dioxide production, water vaporization, oxygen consumption, and heat elimination, even in periods as short as one hour.

Each apparatus has been first tested as a calorimeter by developing heat electrically inside the chamber. Under these conditions a number of experiments show that the two calorimeters give extremely accurate results. A sample experiment is here given:

Record of Heat Developed in Electrical Check Experiment with Chair Calorimeter, October 14, 1909. (1-hour Periods.)

Period.	Theory.	Found.	Percentage found.
	calories.	*calories.*	
First	87.1	86.9	99.8
Second	87.4	88.0	100.7
Third	86.9	86.6	99.7
Fourth	86.9	86.3	99.3
Total	348.3	347.8	99.9

Using the electrical method of control, it was possible to determine the hydrothermal equivalent of the respiration calorimeter by introducing a certain amount of heat into the chamber and allowing the temperature of the apparatus to rise slowly. Obviously in this operation the heat brought away by the cooling water-current was less than that introduced by the amount absorbed by the chamber as its temperature rose. This amount gave accurate data for computing the hydrothermal equivalent of the apparatus. The reverse operation was then carried out, namely, the rate of withdrawal of the heat by the water-current was arbitrarily adjusted so as to cool the whole chamber somewhat and the excess of the heat withdrawn over and above that developed by the electric current gave means for computing the hydrothermal equivalent of the chamber. With the bed calorimeter this was found to be 19.5 kg. of water, and with the chair calorimeter 21 kg. of water.

The most rigid control, however, is obtained in experiments in which a definite amount of alcohol is burned inside the chamber and all four of the factors are measured. The results of an experiment of five consecutive 1-hour periods is given in the table herewith:

Alcohol Check Experiment. Chair Calorimeter, November 18, 1909. (1-hour Periods.)

Period.	Alcohol burned.	Carbon dioxide.			Oxygen.			Water-vapor.			Heat.		
		Theory.	Found.	Ratio of found to theory.	Theory.	Found.	Ratio of found to theory.	Theory.	Found.	Ratio of found to theory.	Theory.	Found.	Ratio of found to theory.
	gms.	*gms.*	*gms.*	*per ct.*	*gms.*	*gms.*	*per ct.*	*gms.*	*gms.*	*per ct.*	*cal.*	*cal.*	*per ct.*
First	14.7	26.0	25.5	98.1	28.3	28.2	99.7	17.0	16.7	98.2	86.1	86.1	100.0
Second	14.2	25.1	24.7	98.4	27.4	27.3	99.6	16.5	16.4	99.4	83.3	82.8	99.4
Third	15.1	26.7	26.5	99.3	29.1	28.8	99.0	17.5	17.5	100.0	88.5	88.9	100.5
Fourth	13.9	24.6	24.4	99.2	26.9	26.9	100.0	16.2	16.2	100.0	81.7	79.8	97.7
Fifth	14.6	25.9	25.9	100.0	28.3	28.7	101.4	17.0	16.9	99.4	85.9	88.1	102.6
Total	72.5	128.3	127.0	99.0	140.0	139.9	99.9	84.2	83.7	99.4	425.5	425.7	100.1

To obtain duplicate results in the determination of a single chemical element or radicle by analysis frequently requires a number of determinations, and when two factors are simultaneously determined, as carbon and hydrogen in elementary organic analysis, still greater difficulty is experienced. It can, therefore, easily be seen that the simultaneous determination of four factors presents a problem that is rarely met with in either physical or chemical operations and heretofore never in physiological chemical operations. Indeed, the apparatus has proved as accurate as any chemical process ordinarily used in a laboratory, and it can accordingly be characterized, both calorimetrically and chemically, as an instrument of precision.

(3) The composition of some Bengali food materials. Hope Sherman and H. L. Higgins. Jour. Amer. Chem. Soc., 32, IV, p. 558. 1910.

In this paper are reported analyses of a number of Bengali food materials sent to the Nutrition Laboratory by Captain McCay, Professor of Physiology in the Calcutta Medical College. The materials included wheat, corn, pulse, and rice, all of which are commonly used in the diet of the Bengalis. The analyses were compared with the analyses of American food materials and it was found that the wheat flour as prepared in India had a considerably higher absolute fat content than ordinary American flour. Twenty-three samples were analyzed and the heats of combustion determined.

(4) An adiabatic calorimeter for use with the calorimetric bomb. Francis G. Benedict and Harold L. Higgins. Jour. Amer. Chem. Soc., 32, IV, p. 461. 1910.

In all investigations in calorimetry, the great and serious obstacle is the cooling correction or the interchange of heat between the calorimeter and the surrounding medium. With the new type of calorimeter the temperature of the surrounding medium is arbitrarily controlled so as to always equal that of the calorimeter itself, thus doing away with any interchange of heat. In the investigations described in this paper the Kröker modification of a Berthelot bomb calorimeter was used, although any other bomb can be employed. The calorimeter vessel containing water in which the bomb was immersed is placed inside of a nickel-plated brass can, allowing a certain airspace between the calorimeter can and its outer nickel vessel. This outer vessel is in turn surrounded by a water-jacket whose temperature can be arbitrarily raised by means of an electric heater. A turbine stirrer keeps the water in agitation and a delicate thermometer enables the reading of the temperature. Passing a current of electricity through the electric heater in the outer jacket maintains the temperature of the water at any desired point; and throughout the whole calorimetric operation the temperature difference between the inside and outside is negligible. The apparatus has been most rigidly tested and has given the most satisfactory results. It promises to be an important addition to calorimetric investigation and supplements the admirable calorimeter devised by Richards, Henderson, and Frevert for special scientific experiments.

(5) Elementary analysis by means of a calorimetric bomb. Harold L. Higgins and Alice Johnson. Jour. Amer. Chem. Soc., 32, IV, p. 547. 1910.

In nutrition investigations innumerable analyses of organic materials are involved in which the carbon and hydrogen content must be known. Usually on the same sample there must also be a determination of the heat of combustion. This paper describes a method of carrying out in practically one operation the determination of the heat of combustion of a material and of the carbon and hydrogen. The substance is burned in a calorimetric bomb and the heat eliminated is measured by the rise in temperature of the water in which the bomb is immersed. The organic material after combustion has been converted into carbon dioxide and water. The gases in this bomb are then allowed to escape and samples are taken and analyzed on a Haldane gas-analysis apparatus. By weighing the bomb before a combustion and after the gas has been allowed to escape, it is possible to compute with great accuracy the carbon and hydrogen content. The method has been checked by determining the carbon and hydrogen in pure substances, such as sugar, urea, uric acid, and benzoic acid. The results have been most gratifying, and the method has proved of great service in the routine analyses connected with metabolism experiments.

(6) Respiration calorimeters for studying the respiratory exchange and energy transformations of man. Francis G. Benedict and Thorne M. Carpenter. Publication No. 123, Carnegie Institution of Washington. 1910.

In the two calorimeters described, one of them for bed-ridden patients, the heat eliminated by man is measured by a current of cold water passing through a heat-absorbing system inside the chamber, the mass of water and the temperature-rise being known. Direct measurement of the water vaporized gives the latent heat of water-vapor. By means of a system of thermal

junctions any slight temperature differences between the inner copper wall and an outer zinc wall are constantly noted. The temperature of the zinc wall is arbitrarily adjusted by heating and cooling to maintain it at the temperature of the copper wall, thus holding the calorimeter in an adiabatic condition. The chambers are large enough for a man to remain comfortably seated or lying for several hours, an electric light furnishes illumination, connection is made by call-bell and telephone with the outside, and a supply of air is continually circulated through the chamber and thence through weighed vessels containing sulphuric acid and soda-lime to absorb quantitatively water-vapor and carbon-dioxide. The oxygen consumed is determined by admitting the gas from a weighed cylinder of highly compressed pure oxygen. Analyses of the air residual in the chamber are made at the end of every period and corrections for barometric changes are applied. Electrical resistance thermometers are used to measure calorimeter as well as body temperatures. A stethoscope and pneumograph permit the measurement of the pulse-rate and respiration-rate. A graphic record of the minor muscular movements is also furnished by the tracing of the pneumograph tambour. The apparatus has been most carefully checked as a calorimeter by the development of the heat from a known electrical current inside the chamber, and the accuracy of measurement of all four factors—carbon dioxide, water-vapor, oxygen absorption, and heat production—has been controlled by burning known weights of pure ethyl alcohol. The methods of calculation and the details of the routine of an experiment with man are included. The apparatus has proved highly successful for 6-hour to 10-hour experiments with men and women, and experiments may be subdivided to 1-hour periods with accurate results.

(7) The metabolism and energy transformations of healthy man during rest. Francis G. Benedict and Thorne M. Carpenter. Publication No. 126, Carnegie Institution of Washington. 1910.

In the decade during which the experiments were in progress with the respiration calorimeter at Wesleyan University, Middletown, Connecticut, a large amount of material on the normal metabolism of healthy men and women was accumulated. This material has been in part published in other reports, but much of it has never been published and is collected here for final presentation. Among the subjects discussed in detail are the changes in body-weight, the insensible perspiration, body-temperature with its variations and fluctuations, and pulse-rate. By means of the respiration apparatus, important data with regard to the vaporization of water from the body of the subject were accumulated, and these are discussed at some length in connection with the elimination of carbon-dioxide, oxygen consumption, and the heat elimination and heat production. Special reference is made to comparisons between the metabolism during sleep and during waking hours and the relationships between the different factors of metabolism. The variations in metabolism due to variations in physical characteristics, age, muscular activity, sex, etc., have received especial attention, including the metabolism of athletes, non-athletes, and women. A number of experiments dealing with the metabolism and energy transformations incidental to simple every-day body movements are also included and tentative tables for the computation of the metabolism of normal individuals with varying degrees of muscular activity are given.

(8) Suggestions regarding research in animal nutrition. Francis G. Benedict. Proceedings Amer. Soc. of Animal Nutrition, p. 20. 1910.

The relation between animal and human nutrition and the importance of coordinating researches in nutrition in general are emphasized in this paper. As studies of the protein requirement of animals are possible in a large number of laboratories that are not equipped for studies of the total metabolism, the suggestions deal for the most part with problems in regard to the protein requirement, such as the minimum and optimum protein requirement, the importance of ash constituents of protein, and the periodic ingestion of protein. Great emphasis is laid upon the importance of using a sufficient number of control animals.

(9) Metabolism in diabetes mellitus. Francis G. Benedict and Elliott P. Joslin. Publication No. 136, Carnegie Institution of Washington. 1910.

In the research reported in this publication the metabolism of 13 diabetic patients was studied by means of the respiration calorimeters of the Nutrition Laboratory. The investigation included 42 experiments lasting 2 to 6 hours, 14 hours after the last meal, together with 11 experiments following the ingestion of food. In these experiments the water elimination, carbon-dioxide production, oxygen consumption, and heat elimination and production were determined, and simultaneous determinations were likewise made of the body-temperature, pulse-rate, and respiration-rate. Besides experiments with the respiration calorimeters, 26 experiments were made with a respiration apparatus which permitted very exact determinations of carbon-dioxide production and oxygen absorption. The urine was collected and the nitrogen and sugar determined in all these experiments.

Complete details of the investigation are reported, together with the clinical history of each case. A summary is given of the gaseous exchange and energy transformations in these experiments and the averages are compared with those for normal individuals in experiments with the same apparatus. The metabolism in diabetes of different degrees of severity is compared.

Some of the other topics discussed are the nitrogen excretion, the dextrose-nitrogen ratio, the vaporization of water from the lungs and skin, and the influence of food on the nitrogen and sugar excretions, on the respiratory exchange, and on the total katabolism. The report concludes with a discussion of practical features in the treatment of diabetes on which light has been thrown by this investigation, including a consideration of the quantities of food allowed diabetic patients, the restriction of the diet, and the advisability of making the diabetic sugar-free. The value of the respiration calorimeter in studying diabetes mellitus is shown and a number of suggestions are made for further investigations on this subject.

(10) The influence of mental and muscular work on nutritive processes. Francis G. Benedict. Proc. Amer. Phil. Soc., 49, p. 145. 1910.

After considering in a non-technical way the fundamental principles involved in the study of nutrition, including a brief description of the respiration calorimeter, some of the results of more general interest in regard to the average normal output of carbon dioxide and heat from the body during the day and during different conditions of muscular work are presented. These are shown in table 1.

TABLE 1.—*Average Normal Output of Carbon Dioxide and Heat from the Body.*

Conditions of muscular activity.	Average quantities per hour.	
	Carbon dioxide.	Heat.
	gms.	*cals.*
Man at rest, sleeping	25	65
Man at rest, awake, sitting up	35	100
Man at light muscular exercise	55	170
Man at moderately active muscular exercise.	100	290
Man at severe muscular exercise	150	450
Man at very severe muscular exercise	210	600

The method of making a rough calculation of the average daily output of the heat from a man is given in table 2.

TABLE 2.—*Average Daily Output of Heat of a Man at Light Muscular Work.*

Daily program.	Heat output.
	cals.
At rest, sleeping, 8 hours, 65 calories per hour	520
At rest, awake, sitting up, 6 hours, 100 calories per hour	600
Light muscular exercise, 10 hours, 170 calories per hour	1,700
Total output of heat, 24 hours	2,820

Since muscular work plays such an important rôle in gross metabolism, it is of interest to see to what extent mental work affects metabolism, and a brief résumé of previously published experiments in which students wrote their college examinations while inside the respiration chamber is given in this paper. No effect of mental work on metabolism was noticeable.*

After considering the results of excessive muscular work,* the conclusion is drawn that in general if the appetite is ordinarily followed it will result in a most perfect adjustment of the food intake and the food requirement. Obviously it is important to select foods that agree with a person; excessive amounts of sweets and foods difficult of digestion are certainly to be avoided, but whether the no-breakfast, no-dinner, or no-supper plan be followed, it is absolutely certain that in the course of 24 hours, or perhaps in the course of a week, the amount lost in the meals voluntarily given up will be compensated by the increased consumption at other meals.

* See Year Book, Carnegie Institution of Washington, 1908, p. 190.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. Bauer, Director.

GENERAL SUMMARY.

It is now somewhat over two centuries ago that the first attempt at an ocean magnetic survey was made, the originator and leader of the expedition being the famous astronomer, Edmund Halley, of whom so much has been written recently in connection with the comet named after him. While a great deal has been said of Halley's various attainments and achievements, but little mention has been made regarding his contributions to the advancement of the art of navigation and to the science of terrestrial magnetism by his "Chart of the lines of equal magnetic variation"—the first of its kind.

The subject of the earth's magnetism had early attracted Halley, and especially the cause of the mysterious change ever going on in the magnetic state of our planet, by reason of which the compass changes its direction, even in so short a period as 5 to 10 years, by an amount sufficient to affect the purely practical interests of surveying and navigation. In 1692 he proposed a unique theory to the Royal Society of London to account for the secular change of the earth's magnetism, and in the year 1698 he set out from England as captain of the ship *Paramour Pink,* under the auspices of the English government, to determine the compass direction in various parts of the oceans. After devoting two years to this task, in which he encountered various difficulties, he laid down the results of his labors on a chart giving the "Lines of equal variation." The first edition of this chart† was published probably in the year 1701, and covered the Atlantic Ocean from about 60° north to nearly 60° south, the lines being in no case extended over land areas. In the following year most likely he published his "World chart," the lines of equal variation covering the Atlantic Ocean, the Indian Ocean, and the extreme western part of the Pacific Ocean.

Since Halley's time the "Charts of the lines of equal magnetic variation," upon which the mariners rely in navigating their vessels, have been repeatedly reconstructed and revised with the aid of newer data. With the advent of iron-built vessels, the acquirement of compass data of sufficient reliability became increasingly difficult; those whose duty it was to keep magnetic charts up to date have thus been frequently unable to gage the precise value of data from modern vessels even when acquired by the most experienced

* Address: The Ontario, Washington, District of Columbia. Grant No. 608. $76,920 for investigation and maintenance during 1910. (For previous reports see Year Books Nos. 3–8.)

† A copy was found by the writer in the British Museum and republished in the January, 1896, issue of the journal Terrestrial Magnetism and Atmospheric Electricity.

navigators. It was necessary to take an average of the data supplied from many different sources in the hope that thereby the effect of the outstanding errors might be reduced to a minimum. Thus, for example, a few years ago an attempt was made by a hydrographic office to improve the existing magnetic charts with the aid of data obtained on vessels the world over in the course of their regular voyages. Circulars were sent to many thousand vessels and many hundred supposedly accurate determinations of the compass direction were received in response and plotted on a world chart. Whenever there were several values for the same region they were found to be so discordant among themselves that the error of even the average results appeared sufficiently large to render it unsafe to make any material alteration in the existing "lines of equal magnetic variation." In brief, to determine possible errors in the present mariners' charts with the appliances and vessels heretofore at the disposal of the hydrographic offices would not only be an exceedingly expensive undertaking, but a most laborious task as well, with the unsatisfactory result, after all had been done, that there might still be errors due to variable effects of the iron of the modern vessel which were not sufficiently eliminated.

It is possible for the *Carnegie*, on a single trip of but twelve days, as, for example, the one in October of 1909 from St. John's, Newfoundland, to Falmouth, England, to uncover errors of practical importance to the mariner because of their consistency and prevalence over long distances. These errors, in general, exceed the corrections on account of the secular change in the compass direction for 10 to 20 years.

The errors found by the *Carnegie* on her trip to Falmouth, as above related, were confirmed on other parts of her first cruise covering the Atlantic as far south as the Madeiras and the Bermudas. Again, for long stretches, systematic and, hence, cumulative errors were disclosed, the charts showing the compass direction, which are now in actual use, being found in error at times as much as 2° to 2.5°. The chief cause for these errors was likewise discovered, viz, that incorrect allowances, for sufficiently long periods, were made in the construction of the charts on account of the secular changes. The "Complete magnetic results of the first cruise of the *Carnegie*" were promptly supplied in manuscript to the leading hydrographic establishments and published in the June 1910, issue of the journal "Terrestrial Magnetism and Atmospheric Electricity." The September issue of the same journal gave an account of the special investigations made in the vicinity of Gardiner's Bay in 1909 and 1910, as also tabular statements showing the distribution and run of the chart errors revealed by the *Carnegie's* first cruise. The errors disclosed may be summarized as follows:

Except for the portion of the cruise from 48.5° N., 47° W., to Falmouth Bay, and thence to Madeira, all charts show too low west magnetic declination (variation of compass) over the portion of the Atlantic Ocean covered by the *Carnegie*. While the error is in general less than a degree, it is unfortunately in the same direction for about 5,000 miles, and hence the result-

ing error in a ship's course based on the present mariners' charts may be cumulative and ultimately reach a considerable amount. The maximum chart error at any one point may be from 1.3° to 2.6°, according to the chart used.

The average chart error (sign not being considered) for magnetic dip approximates 1.5° to 2.° the maximum error for the British chart being 2.5° and that of the German 4.4°. The British chart gives, in general, too small dips and the German too large ones.

The average chart errors for magnetic horizontal intensity, disregarding sign, approximate 8 units in the third decimal C. G. S.; the maximum error is about 15 units for either British or German chart. For the greater part, both charts give, in general, too high values.

The *Carnegie's* first cruise covered about 8,000 nautical miles and extended from September 1, 1909, to February 1910. On June 20, 1910, she began her second cruise, which will extend around the globe, with an aggregate length of about 65,000 nautical miles and requiring about 3 years for completion. Special tests made in Gardiner's Bay, off Long Island, again showed that, with the appliances and methods used aboard the *Carnegie*, the magnetic elements can be determined with an accuracy sufficient for all purposes, practical as well as scientific.

Leaving Greenport, Long Island, June 29, she arrived off Port Mulas, Porto Rico, July 24. On this trip errors in the mariners' compass charts of 2° to 2.5° in the North Atlantic were once more revealed, as also similar errors to those found on the first cruise in the dip and the magnetic force. Reviewers of the work already accomplished by the *Carnegie* have made the statement that even if this vessel should do nothing more she has already justified her existence.

The projected circumnavigation cruise of the *Carnegie* can be briefly indicated by the following ports to be visited: Greenport, Long Island; Vieques, Porto Rico, where she arrived July 24; Pará, where she arrived September 24, and Rio de Janeiro (November 1910); Montevideo and Buenos Ayres (December 1910); Tristan da Cunha and Cape Town (March 1911); Colombo (Ceylon) and Bombay, Mauritius, and Batavia (October 1911); Manila (December 1911); Samoa (March 1912); Acapulco, Mexico (June 1912); Cape Horn and South Georgia Island (November 1912); Cape Town (January 1913); Vieques, Porto Rico (April 1913); Greenport, Long Island (June 1913).

On the accompanying map, the status of the magnetic work accomplished both on land and ocean by the Department up to October 31, 1910, is shown in red. The cruises of the *Galilee* in the Pacific Ocean, 1905–08, and of the *Carnegie* in the Atlantic Ocean, 1909–10, are shown by full red lines. The uncompleted portion of the circumnavigation cruise of the *Carnegie* is shown by broken red lines (return portion is indicated by dots and dashes).

Besides the important results in magnetism obtained by the *Carnegie*, there has also been acquired other information of interest to the mariner, viz, data for testing and revising the corrections which must be applied, on account

of atmospheric refraction, to astronomical observations for determining a ship's position. So, again, there have been obtained results of value to the student of atmospheric electricity.* The *Carnegie* also contributes useful meteorological data to meteorological institutions. In brief, every opportunity is embraced by the scientific personnel to obtain information of practical as well as of scientific value.

From the detailed statements below of the field work, it will be seen that the land work during the present fiscal year consisted in the satisfactory completion of important work in Africa by Professors Beattie and Morrison, who, as will be recalled, were associated with the Department during 1909, and in Turkey and Asia Minor by Observers Pearson and Sligh.

Of considerable importance for the rapid execution of land magnetic work was the purchase of a 35-foot launch supplied with an 18 H. P. Remington oil-engine for use along the rivers in the portions of South American countries where proper transportation facilities could not be readily had. This expedition is in charge of Observer C. C. Stewart; the launch, which is called *El Imán* (Spanish for the magnet) was shipped to Manáos, Brazil, from which point Mr. Stewart started his work.

Satisfactory progress, as will be seen from the detailed statement, has likewise been made in the office work and in theoretical investigations. The rapid reduction and publication of the results of the *Carnegie* has already been noted. As a result of intercomparisons of magnetic outfits made by the observers of the Department in all parts of the globe, it is now possible to make a final publication of the magnetic data thus far obtained by the Department, all reduced to a common basis; the manuscript of this report is in good state of progress and is rapidly approaching completion.

In the workshop of the Department there have been constructed various instruments of special design and of light weight, which promise to further facilitate the field operations, especially in matter of transportation.

Of theoretical interest are the results obtained with regard to magnetic storms as published in recent issues of the journal "Terrestrial Magnetism and Atmospheric Electricity." The main conclusions were as follows:

Magnetic storms do not begin at precisely the same instant all over the earth. Those beginning abruptly, in which the effects are in general small, appear to progress over the earth more often eastwardly, though also at times westwardly, at a speed of about 7,000 miles per minute, so that a complete circuit of the earth would require 3.5 to 4 minutes. For the bigger and more complex magnetic disturbances the velocity of propagation may be cut down considerably. The time of beginning of the disturbance may be appreciably different for the various magnetic elements, according to the character of the disturbing causes.

* See Observer Kidson's report, "Atmospheric electricity observations on the first cruise of the *Carnegie*," Journal "Terrestrial Magnetism and Atmospheric Electricity," June 1910.

The manifestations of solar activity, with their resulting emanations and radiations, seem not to be the direct but the indirect cause of the earth's magnetic storms. Their effect appears to be more in the nature of a releasing or "trigger" action, setting in operation electric energy already in existence in the upper regions of the atmosphere; terrestrial sources in reality, however, supply the energy required for the magnetic storm. To account then for the well-established, general relationship between magnetic disturbances and the sun-spot period, we must suppose that the radiations which alter the conductivity of the atmosphere vary in their amount and intensity in accordance with the periodicity of the solar phenomena.

In conclusion, it is but due to the members of the departmental staff, in general, and specifically to the commander of the *Carnegie,* Mr. W. J. Peters, and to the magnetician in charge of office, Mr. J. A. Fleming, that acknowledgment is made hereby of the effective and cordial assistance rendered in the successful execution of the various operations of the Department.

DETAILS OF MAGNETIC WORK DURING THE YEAR, NOVEMBER 1, 1909, TO OCTOBER 31, 1910.

LAND WORK.

Africa.—The itinerary for work, as outlined in last year's report, entrusted to Dr. J. C. Beattie, Research Associate, assisted by Prof. J. T. Morrison, Magnetic Observer, has now been completed. An inspection of the work shown for Africa on the accompanying map (plate 5) will serve to give some idea of the numerous data obtained in a laborious campaign well carried out. The distribution of stations occupied during October 1908 to January 1910 is as follows: Jointly by both observers, 6 in Belgian Kongo, 1 in Cape Colony, 1 in Egypt, 1 in England, and 39 in Rhodesia—in all 48; by Dr. Beattie, 36 in Cape Colony, 45 in German Southwest Africa, 60 in German East Africa, 3 in Rhodesia, and 33 in the Uganda Protectorate—in all 177; by Professor Morrison, 35 in British Central Africa, 28 in British East Africa, 4 in Cape Colony, 10 in German East Africa, 24 in German Southwest Africa, 6 in Portuguese East Africa, 15 in Rhodesia, and 1 in Zanzibar—in all 123. The total number of stations is 348. Such a large number of stations was made possible by the plan adopted of taking observations at each camping-place. The results will accordingly furnish also knowledge regarding locally disturbed regions along the line of work. In addition to the results obtained on this expedition, Dr. Beattie has placed in the hands of the Department for reduction observations made by Professor Morrison and himself at 15 stations during June and July 1908, in Cape Colony, Natal, and Transvaal; also observations by himself during January to February 1907 at 18 stations in Cape Colony. Intercomparisons of standards were made for the instruments used in this work at the magnetic observatories at Helwan and Kew.

China.—No field work was done in China during the year. However, the necessary preparations have been made for extended campaigns in following

years under the charge of the President of the Canton Christian College, who has already conducted magnetic work in China for the Department in the years 1905 to 1908, as per previous reports. The plans as contemplated, in connection with the work already completed by Department observers, provide for the completion of a general magnetic survey of the Chinese Empire. During September Dr. Edmunds made at Washington a series of complete standardization observations for the instrumental outfit to be used by him.

Canada.—During August to October the Department has cooperated with the expedition of Professors Raymond McFarland, T. C. Brown, and P. N. Swett, of Middlebury College, Middlebury, Vermont, from Lake St. John to Lake Mistassinni and return. The magnetic observations have been made by Professor Swett and 6 stations have been occupied. During June and July Professor Swett made complete standardization observations of the instrumental outfit at Washington and occupied a repeat station at Middlebury.

It has again been the good fortune of the Department to be able to cooperate in instrumental matters with Prof. R. F. Stupart, Director of the Meteorological Service of Canada, who has sent an observer to obtain magnetic data along the Mackenzie River.

Turkey and Arabia.—Mr. J. C. Pearson, Magnetic Observer, continued work in Turkey until relieved in January by Mr. W. H. Sligh, Magnetic Observer. Mr. Pearson, after securing observations during November 1909, at 3 stations along the southern coast of the Black Sea in Turkey in Asia, proceeded to Constantinople. After complete intercomparisons of instruments had been made at the magnetic station, Robert College (near Constantinople), Mr. Sligh took up operations in Palestine, Syria, Arabia, Mesopotamia, and the islands of Rhodes and Cyprus. Up to the end of July he had established 44 stations. In August Mr. Sligh left Constantinople overland for Bagdad and Busra, which latter point he will probably reach early in January 1911. During August to October about 25 stations will be occupied. This work and that by Mr. Pearson will practically complete a general magnetic survey of Asia Minor and Persia, as well as a part of Arabia.

Austria, England, and Germany.—Upon completion of the work at Constantinople Mr. Pearson made intercomparisons of standards at the magnetic observatories, Pola (Austria), Potsdam (Germany), Kew (England), and Cheltenham (United States), thus completing a very valuable series of intercomparisons of standards; in his previous work he had made similar observations at Kew, Helwan (Egypt), Tiflis (Transcaucasia), Tashkent (Russian Turkestan), and Cheltenham. Acknowledgment must be made of the very cordial assistance rendered the Department in the execution of this work by the Directors of the various observatories as well as by their assistants. Those in charge were Mr. B. F. E. Keeling, Helwan; Dr. Charles Chree, Kew; Dr. M. Ossipov, Tashkent; Dr. Stephen v. Hlasek, Tiflis; Dr. Adolf

Schmidt, Potsdam; Capt. W. v. Kesslitz, Pola, and Messrs. R. L. Faris and J. E. Burbank, Cheltenham.

South America.—Messrs. C. C. Stewart, Magnetic Observer, and W. C. Hamer, Launch Engineer, left early in June for Manáos, Brazil, to make preparations for the magnetic survey along the navigable rivers of the Amazon system. The launch *El Imán,* referred to in the general summary above, was received by them at Manáos early in August and at once placed in commission. The observations at Manáos being completed, the party left on August 21, 1910, for Iquitos, Peru, where they arrived September 30, 1910, having occupied 19 stations en route. From Iquitos the work will be extended along the Ucayali River as far as is possible into southern Peru, and thereafter along the navigable rivers in northern Peru and Ecuador. At the end of the fiscal year there will have been occupied in all about 30 stations, which will afford very valuable data. This work is being done in cordial cooperation with the existing organizations in the countries penetrated.

Miscellaneous.—In connection with the operations of the *Carnegie,* land stations have been established at the following points: Funchal, Madeira; repeat stations at Agar's Island and Hunt's Island, Bermuda; repeat stations at Bronx Park and Greenport; Vieques Magnetic Observatory and repeat station on Culebra Island, Porto Rico; and repeat station at Pinheiro, Brazil. New stations were also established by the Director at Plum Island, Ram Head (Ram Island), and Shelter Island, United States, in order to assist in determining the character and extent of the prevalent local disturbances.

OCEAN WORK.

The *Carnegie* left Falmouth, England, upon the completion of the work there on November 9, 1909, and arrived at Funchal, Madeira, on November 24, 1909. Owing to the pronounced local disturbances at Funchal, no standardization observations were made. The longest leg of the first cruise of the *Carnegie,* viz, between Funchal and Hamilton, Bermuda, was completed between December 1, 1909, and January 8, 1910, under very favorable conditions. The constants of the instruments were determined at Agar's Island and Hunt's Island and the final leg of the first cruise to New York begun on January 28, 1910. After a very stormy trip, which amply proved the seaworthiness of the vessel, the *Carnegie* came to dock in Brooklyn on February 17, 1910.

The alterations in the vessel and additions, found desirable as the result of the first cruise, were completed by the Tebo Yacht Basin Co. in time to permit the *Carnegie* to set out from Brooklyn upon a three years' circumnavigation cruise on June 20, 1910. In connection with these alterations, which were almost wholly in the auxiliary propulsion plant and its general arrangement, acknowledgment must be made of the cordial and effective assistance rendered by the architect of the *Carnegie,* Mr. H. J. Gielow; by the constructing firm under the management of Mr. Wallace Downey; by

Mr. C. D. Smith and Prof. W. C. Bauer, consulting engineers; by Mr. James Craig, jr., the builder of the engine, and by Mr. D. F. Smith, the engineer in charge.

The *Carnegie* first proceeded to Greenport, Long Island, and "swung ship" in Gardiner's Bay on June 23 and 25 at the same place as last year. Having completed the determinations of instrumental constants, course was set for Vieques, Porto Rico, on June 29, via latitude 34° north and longitude 46° west. She was visited and inspected at Greenport by President Woodward in company with the Director. After an unusually favorable cruise, during which observations of all the elements were possible on all but two days, Vieques was reached on July 24. At this point opportunity was afforded, through the courtesy of Superintendent O. H. Tittmann, of the United States Coast and Geodetic Survey, to intercompare all of the instruments with the standards of the Vieques Magnetic Observatory. After calling at San Juan, Porto Rico, where valuable assistance was rendered the vessel by Commodore Karl Rohrer, of the United States Naval Station, magnetic observations were secured at the repeat station on Culebra Island; the *Carnegie* left thence for Pará, Brazil, where she arrived September 24, 1910, having again in this leg of the cruise encountered unusually favorable conditions for work. Upon completion of the shore work at Pinheiro, the *Carnegie* left Pará on October 15, 1910, and is en route to Rio de Janeiro at the end of the fiscal year.

The present personnel of the *Carnegie* consists of the following:

Scientific staff: L. A. Bauer, Director; W. J. Peters, in command of vessel; C. C. Craft, surgeon and magnetic observer; E. Kidson, magnetic observer; H. D. Frary, magnetic observer; C. R. Carroll, meteorological observer and clerk.

Sailing staff and crew: F. S. McMurray, first watch officer; M. Clausen, second watch officer; A. Jorgensen, third watch officer; M. G. R. Savary, engineer; eight seamen; one mechanic; two cooks; two cabin boys.

The personnel up to the completion of the first cruise in February was the same as stated in the annual report of the Director for 1909.

OFFICE WORK.

Excellent progress has been made during the year with the work of computation and this is practically complete for all work in hand to date. These reductions involve very extensive discussions of the methods and constants of instruments used. The first computations of the observations at some 350 stations since November 1908, in the African campaign of Dr. Beattie and Professor Morrison, have been completed. The preparation of the data obtained by the Department both at sea and on land for publication is well advanced and very nearly completed for the operations to date. The question of differences in various standards used by different governments and institutions has been studied at length and the reductions of the intercomparison results so far obtained at 20 magnetic observatories in all parts of the world have been completed. The constants and corrections to standard have been determined or redetermined during the year for 10 magnetometers, 10 dip

circles, and 1 earth inductor. This work has been done invariably by the method of simultaneous comparison with standard instruments. The instruments used for the observations in atmospheric electricity on board the *Carnegie* have been tested and standardized. The various forms for sea and land work have been carefully revised and improved and new forms developed to facilitate as well as to give greater uniformity of method for all observations and reports. General and particular instructions have been prepared as necessary.

The compilation of past magnetic data, the indexing of current literature, and abstracting of publications of especial interest have been continued. Requests for data and information have been numerous and varied; responses have been made as promptly and in such detail as has been possible. The Government trigonometrical survey of Southern India has been supplied for mapping purposes with the data obtained in Persia; a preliminary isogonic chart of the North American continent has been constructed at the request of Professor Chant, of the University of Toronto; ocean magnetic data have been supplied the hydrographic offices of various governments; details of instrument construction have been supplied to the United States Geological Survey; tests of improved forms of compass needles have been made for manufacturers of surveying instruments, etc.

Some time has been given to the magnetic work to be undertaken in cooperation with Capt. R. Amundsen in his coming polar expedition and the preparation of the magnetic outfit, the observer-in-charge, Dr. H. M. W. Edmonds, being engaged at the office from January to June partly on this special work and partly on the regular work of the Department. Extensive preparations were made for the work to be taken up in South America and in China in the present and coming years. In connection with the alterations of the *Carnegie,* much attention has been given in the office to the perfection of details, consideration of materials, tests, and plans.

SHOP WORK.

Magnetometers Nos. 12, 13, 14, and 15 have been completed during the year; No. 15 was constructed at the request of the Canadian government for the use of the meteorological service of Canada. These instruments have been found very satisfactory and their portability and light weight makes them peculiarly suited for survey work in countries where transportation is difficult. Magnetometer No. 14 is a universal instrument of new design; it is suited for the determination of all the magnetic elements and geographical position and azimuth. The weight of this instrument with its accessories, but without packing, is under 15 pounds; the packing will increase this to about 30 pounds (the instrumental outfit and packing heretofore used in the earlier work of the Department weighs considerably over 100 pounds; thus some idea of the compactness of the present outfit may be obtained). Magnetometers Nos. 12, 13, and 15 were especially designed as theodolite magnet-

ometers for the determination of all the elements except inclination; with accessories and packing these weigh about 25 pounds each. Full descriptions and details of these instruments are to be given in an early number of the journal "Terrestrial Magnetism and Atmospheric Electricity." Magnetometers Nos. 16 and 17, similar to No. 12, are now under construction.

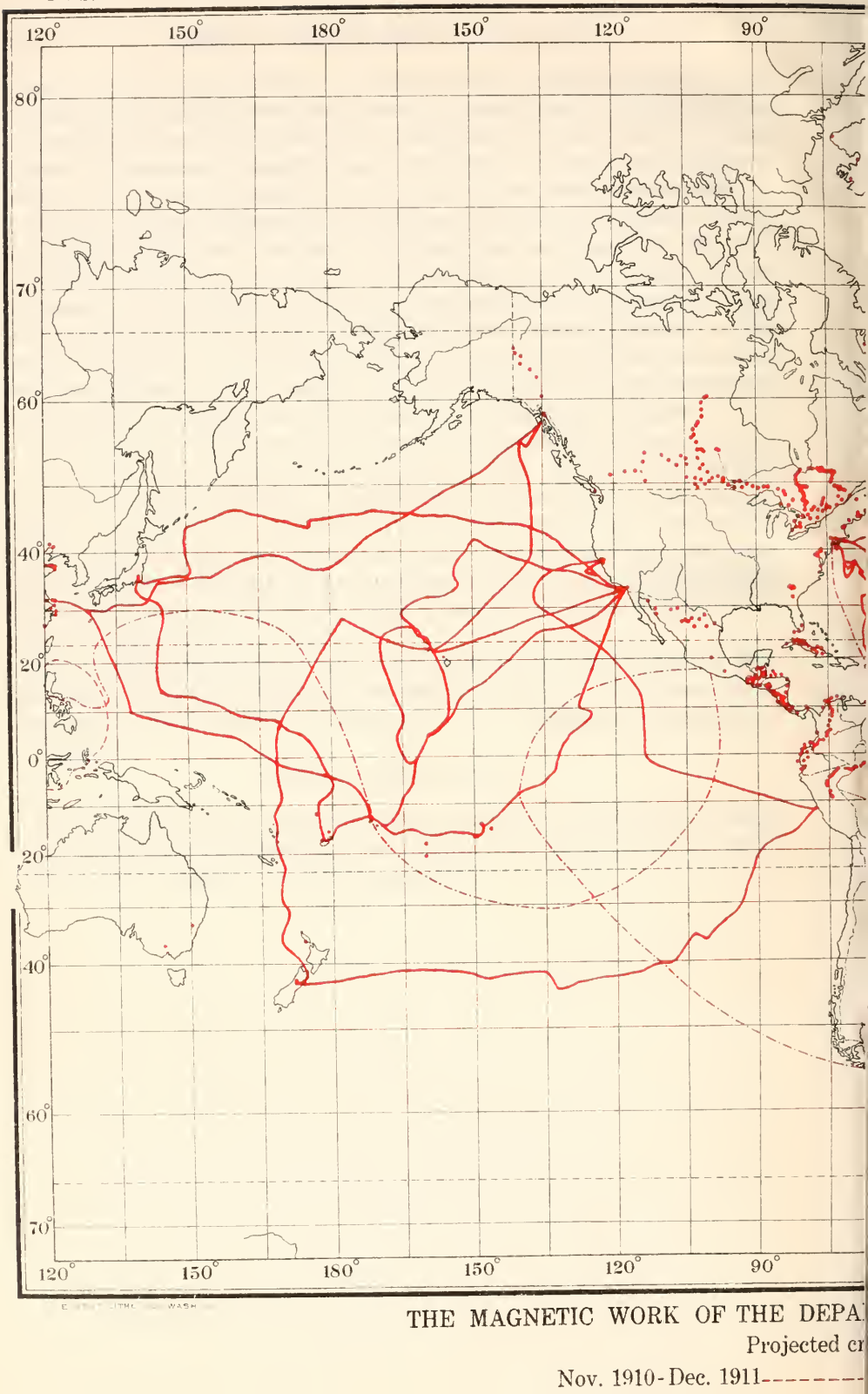
A special form of sighting device has been provided for deflector No. 3, at present used on the *Carnegie*. The plans have been made for the construction of deflector No. 4, which will embody further improvements, as indicated by the experience during the first cruise of the *Carnegie*. This instrument is now under way. Several pieces of special apparatus for the study of atmospheric electricity and radioactivity of rain and sea water have been constructed for the *Carnegie*; the old equipment of such instruments has also been thoroughly overhauled and put in first-class condition.

During the year numerous improvements and repairs have been made on the outfits in hand; it has thus been possible to keep all instruments in first-class order and in commission. This has been particularly the case for the dip-circle needles, for which new pivots have been supplied as found necessary to replace inferior or rusted ones. The facilities of the shop have been increased by the installation of an engraving machine, and a dividing engine has been ordered; it will thus be possible soon to construct *all parts* of our instruments ourselves.

Mr. Adolf Widmer continues as Chief Instrument-maker under the general supervision of the magnetician-in-charge. Owing to the increase in the shop work, a second instrument-maker, Mr. E. K. Skonberg, was appointed on April 1.

SPECIAL INVESTIGATIONS.

(See statement above in general summary regarding investigation of magnetic storms and intercomparisons of magnetic instruments, as also list of publications by members of the Department.)



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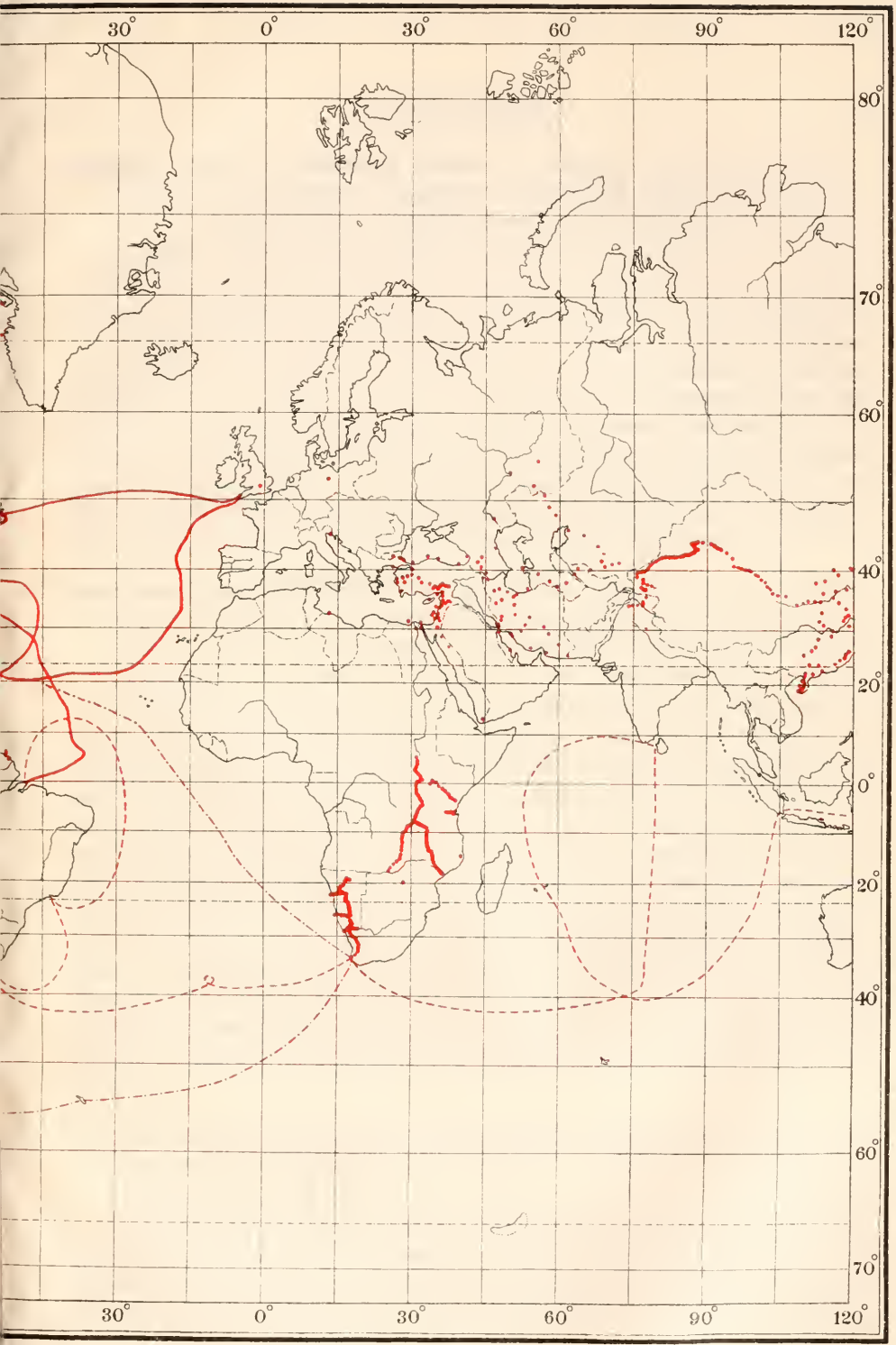

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the Carnegie
Jan. 1912-June 1913

ARCHEOLOGY.

American School of Classical Studies at Athens. James R. Wheeler, Chairman of Managing Committee, Columbia University, New York, N. Y. Grant No. 619. *Maintenance of a fellowship in architecture at Athens.* (For previous reports see Year Books Nos. 4–8.) $1,000

Mr. Dinsmoor has continued his work on the western slope of the Acropolis and has published an elaborate article on the Gables of the Propylæa in the American Journal of Archæology (vol. XIV, 1910, pp. 143–184, 2 plates, 15 text-figures). He has also discovered the site of the choragic monument of Nicias, the position of which has hitherto been misunderstood, and has written an article on this monument, which has been sent to the editors of the Journal of Archæology. He has also given the director of the school assistance in certain work at Corinth which involved architectural study. His chief work, however, has been in Athens, as described above. The officers of the school are much gratified with what he has accomplished.

American School of Classical Studies in Rome. Andrew F. West, Chairman of Managing Committee, Princeton University, Princeton, N. J. Grant No. 615. *Continuation of investigations in the field of Roman archeology.* (For previous reports see Year Books Nos. 4–8.) $2,000

Dr. Elias A. Loew (Carnegie Associate 1907–1908) continued his valuable work on the *Scriptura Beneventana.* One-half of this work is in press. It comprises about 100 fac-similes of the writing of Benevento, published by the Palæographical Society; a preface will accompany the whole. The second half is a study of the script in the form of a lengthy monograph, to be published independently of the first half. This monograph is well advanced towards completion. The coming year (Dr. Loew has been reappointed) will see the completion of this work, which bids fair to be of great historical value. Dr. Henry H. Armstrong, Carnegie Research Associate, made a topographical and historical study of the ancient Privernum in the Pomptine Marshes, between Rome and Terracina. He discovered a large quantity of new matter, both on the spot itself and in the search of the archives. His work is in process of publication by the American Journal of Archæology.

W. Max Müller, Philadelphia, Pennsylvania. Grant No. 646. *Continuation of archeological research in Egypt.* (For previous reports see Year Books Nos. 3, 5, and 6.) $2,000

Dr. Müller left New York May 12, first going for conferences with some leading scholars and for consultation of libraries, etc., to London, Oxford, Paris, Strassburg, Munich, and Vienna; by way of Constantinople, he arrived at Cairo in the first days of July, and worked through the new acqui-

sitions of the museum, also pursuing linguistic and ethnologic studies in the interesting negro quarter of the Egyptian metropolis. Studies in the field were begun in August, and were pursued especially at Thebes, where the vast temple of Amon still yields not only new details of inscriptions and pictures, but some of the largest inscriptions known. Dr. Müller continued the collection of ancient ethnographic pictures. His work at Philæ was left for the second half of September. Much valuable material here has been washed away within the last couple of years, but some good pieces are left for copying.

Esther B. Van Deman, Rome, Italy. Grants Nos. 565 and 640. *Researches in Roman Archeology.* (For previous reports under auspices of Roman School see Year Books Nos. 6, 7, and 8.) $2,200

The months of July, October, and November, 1909, were spent largely in arranging the data already collected and in the preparation, from this material, of a working outline of the Handbook on Roman Concrete Construction. In December the regular study of the monuments was resumed; the greater part of the time, until April 15, was devoted to the monuments belonging to the more difficult periods, namely, those of the late Republic and Augustus, and of the late Empire. In connection with the earlier periods it became necessary to determine the levels of the Forum and Palatine and the dates to be assigned to each, in order to classify more certainly the materials found at the various levels. The work in the Forum, which is almost completed, has yielded many results important for the topography of the region (including the location of several monuments as yet unplaced) as well as for the subject in hand. The work on the Palatine has been postponed, in view of the expected publication of a set of measurements made under the direction of the government.

During March much light was thrown upon the construction of the Roman vaults by the valuable suggestions of Miss Gertrude Bell, whose work has included a study of that subject in the East.

During the fourteen months four trips have been made. The first of these, from the 5th to the 20th of August 1909, included brief visits to Potenza, Bari, Brindisi, and other points in southeastern Italy. The results were wholly negative, since no traces of the use of concrete by the Romans were found.

The second trip, in addition to two weeks of rest in Switzerland, included the study of the monuments in Aosta, Como, Milan, Macerata (*Helvia Recina*), Urbisaglia, Tolentino, and Cagli. The principal result was the discovery of a type of Roman concrete and brick construction in Italy distinct from that found at Rome, and which influenced directly the medieval construction in the same districts.

During the month from April 15 to May 18 the leading ancient sites of Sicily were visited. Among these were Segesta, Selinunte, Trapani, Mount

Eryx, Girgenti, Syracuse, Catania, Centuripe, Taormina, Spadafora (an ancient brick-kiln in the vicinity), Tindari, Solunto, and Palermo. In western Sicily and Syracuse (with the exception of the amphitheater) no traces of concrete construction were found. In Centuripe, Catania, and Palermo many remains exist showing the use of concrete construction by the Romans, while the monuments of Taormina, especially the theater, are among the finest brick-faced concrete structures as yet found. These monuments may, it is hoped, throw some light on the question of the origin of the Roman construction in general.

The object of the fourth trip, from July 23 to August 8, was to determine, if possible, the extent of and methods used in the concrete constructions in the vicinity of Ancona, among the most important districts for the study of the problems now in hand. The points visited were Rimini, Fano, Pesaro, Ascoli Piceno, Urbisaglia, Gubbio, Spello, Terni, Narni, and Amelia, in all of which places, except Fano and Pesaro, were found valuable remains in concrete faced with stone or with brick.

In connection with these trips, a list (as yet incomplete) has been made of the most important centers where there exist Roman concrete remains, showing the variations in material and technique from the concrete structures in Rome and its immediate vicinity.

BIBLIOGRAPHY.

Fletcher, Robert, Army Medical Museum, Washington, District of Columbia. Grant No. 634. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–8.) $12,500

The volume of the Index Medicus for the year 1909 was duly issued. Readers are cautioned that additional headings of subjects are made during the publication of the volume to correspond to advances in pathology in particular. For example, in a recent number the heading "Epidemic Poliomyelitis" brings together the many indeterminate names for the prevailing and alarming epidemic disease known to some extent as "infantile paralysis." An interesting illustration of the world's progress is the citation in the pages of the Index Medicus of medical periodicals in languages not previously exhibiting works of the kind. Some of these may be mentioned: as, one in the Catalan dialect, which curious tongue contains relics of the old Basque language of primitive Spain; others are Bulgarian, Little Russian, Servian, Slavonian, and even one of Esperanto!

CHEMISTRY.

Acree, S. F., Johns Hopkins University, Baltimore, Maryland. Grant No. 616. *Continuation of study of tautomerism and catalysis.* (For previous reports see Year Books Nos. 4–8.) $1,000

Work on tautomerism and catalysis has been continued with the cooperation of Dr. B. B. Turner, Dr. Sidney Nirdlinger, Dr. H. C. Robertson, Dr. S. K. Loy, Mr. E. P. Doetsch, N. E. Loomis, and Mr. E. K. Marshall. Some especially interesting results were secured at —70° C. in the work on tautomeric compounds. This line of investigation will be continued at still lower temperatures.

During the year an excellent system of resistance thermometry has been developed by Messrs. Turner and Marshall, with the cooperation of Drs. Dickinson and Mueller, of the Bureau of Standards. The special features of the Wheatstone bridge and the thermometers enable us to measure temperatures with an accuracy of 0.001° C., or better.

A system of standard calomel cells has been perfected; pairs of these have not varied in their electromotive force in one year as much as 0.00001 volt.

The following papers have appeared during the year:

On the Reactions of Diazoalkyls with 1-Phenyl-2-Methylurazole. By Sidney Nirdlinger and S. F. Acree. (American Chemical Journal, 43, pp. 358–384.)—In this article are discussed some new methods of studying the reactions of tautomeric acids. The results give strong evidence of the existence of two tautomeric acids in solutions of 1-phenyl-2-methylurazole.

Note on the Reactions of Diazoalkyls with 1-Phenyl-2-Methylurazole. By Sidney Nirdlinger, E. K. Marshall, jr., and S. F. Acree. (American Chemical Journal, 43, p. 424.)—This is a continuation of the preceding article and embodies the results of experiments at —70° C.

On the Salts of Tautomeric Compounds: Reactions of Urazole Salts with Alkyl Halides. By R. F. Brunel and S. F. Acree. (American Chemical Journal, 43, pp. 505–553.)—Dr. Brunel prepared a large number of derivatives of phenylurazole and performed a number of quantitative experiments to secure light on tautomeric reactions. There is a full discussion, which shows that the evidence secured harmonizes much better with our theory of tautomeric compounds than with the theories of other workers.

On the Rearrangement of the Tautomeric Salts of 1,4-Diphenyl-5-Thionurazole and 1,4-Diphenyl-5-Thiolurazole. By Sidney Nirdlinger and S. F. Acree. (American Chemical Journal, 44, pp. 219–251.)—In this article is an excellent example of the use of physical organic methods in the determination of the constitution of these urazoles, which had been given wrongly by others for twelve years. These acids and their salts were shown to rearrange into each other and to give characteristic derivatives in harmony with our theory.

Ueber die Quantitative Bestimmung von Diazoalkylen. By E. K. Marshall, jr., and S. F. Acree. (Berichte d. d. Chem. Ges., 43, p. 2323.)—Mr. Marshall has worked out an accurate method for analyzing a solution of diazoalkyls, none having existed for these organic compounds.

Bancroft, W. D., Cornell University, Ithaca, New York. Grant No. 609. *Systematic study of alloys.* (For previous reports see Year Books Nos. 2–8.) $1,500

Owing to the failure to obtain a suitable temperature-regulator and to the delay in obtaining a suitable temperature-recorder, no thermometric measurements have yet been made upon the iron-carbon alloys. The microscopic examination is practically finished and much time has been spent in collating work of other investigators; when properly interpreted this other work confirms the conclusions drawn from the present investigation in an extremely satisfactory manner. There seems good reason to suppose that the substance which crystallizes from the melt is δ iron and not γ iron, as usually supposed. It is now sought to determine the limits of the δ and the γ fields. The copper-tin diagram has been finished. One of the two unexplained heat-changes has been shown to be due to the presence of free tin where it did not belong. Annealing for three months at 210° removed this. The other heat change at 188° has been shown to be due to a second modification of the ϵ phase.

The work on the tensile strength of the zinc-aluminum alloys has been finished. It was previously reported that the tendency of certain of these alloys to break down was due to the formation of a new phase of unknown composition, but further investigation shows that the trouble is due to the action of furnace gases on the melt.

An extended investigation has been made on the electrolytic corrosion of copper, tin, nickel, cadmium, zinc, and iron. The corresponding chemical corrosions are only partially finished; but it is believed that this work will be completed before the end of the winter.

Baxter, Gregory P., Harvard University, Cambridge, Mass. Grant No. 623. *Determination of atomic weights.* (For previous reports see Year Books Nos. 3–8.) $1,000

With the assistance of the above grant the following researches were carried on under Professor Baxter's direction:

The investigation upon the atomic weights of silver and iodine through the analysis of iodine pentoxide (recently published; see Year Book No. 7, pp. 189–192) was continued by new determinations of the ratio of silver to iodine. Since the percentage of iodine in the pentoxide is obtained by multiplying the ratio of silver to iodine pentoxide by the ratio of iodine to silver, it seemed highly desirable to investigate the latter ratio by as nearly as possible the same method as that used in determining the former ratio. This method consisted in the titration, at very high dilution, of the solutions of weighed

amounts of pentoxide, after reduction to hydriodic acid by means of hydrazine, against weighed nearly equivalent amounts of the purest silver. A few tenths of a milligram excess of silver were always used, and the excess was determined gravimetrically in the filtrate after evaporation.

In the determination of the ratio of silver to iodine, the method was exactly like the one just outlined, except that, instead of iodine pentoxide, iodine was weighed and reduced, with elaborate precautions to prevent loss by spattering or evaporation, with an excess of hydrazine. The titration against weighed equivalent amounts of silver proceeded as above.

The iodine was prepared in part by decomposing very carefully crystallized iodic acid at high temperatures in a current of pure dry air. One specimen of iodic acid, which had been made by the action of pure fuming nitric acid on pure iodine, remained from the previous research. A second specimen was prepared from recrystallized potassium iodate through barium iodate. Still another specimen of iodine was purified by double distillation from an iodide, with intermediate boiling in the form of hydriodic-acid solution to eliminate hydrocyanic acid.

The preparation of the iodine for weighing consisted in sublimation in a current of pure dry air into a weighed tube, of glass in most of the experiments, of quartz in the three final experiments. At first the sublimation was conducted in a hard-glass tube, but in most of the experiments a quartz tube was used for the purpose. Several samples of silver of known purity were employed. In order to prevent or detect occlusion by the silver iodide, the method of analysis was varied by diluting the solutions, more in some cases than in others, before precipitation, but in no case was either the hydriodic-acid solution or the silver-nitrate solution more concentrated than thirtieth normal. Furthermore, although in most of the experiments the silver-nitrate solution was poured into the hydriodic-acid solution, in two experiments precipitation was effected in the reverse fashion. All variations in material and method were without perceptible effect.

In the following table are given the results of all the analyses except one which met with an accident:

No. of analysis.	Weight of iodine in vacuum.	Weight of silver in vacuum.	Weight of silver iodide from filtrate.	Ratio, Ag : I.
	grams.	*grams.*	*gram.*	
1	9.00628	7.65478	0.00022	0.849927
2	13.45067	11.43208	0.00062	0.849905
3	11.86648	10.08602	0.00067	0.849933
4	8.52461	7.24530	0.00070	0.849890
5	6.42840	5.46366	0.00033	0.849902
6	8.30266	7.05651	0.00022	0.849897
7	9.95288	8.45918	0.00030	0.849909
8	6.97131	5.92510	0.00042	0.849899
9	9.38852	7.97952	0.00055	0.849897
10	6.56811	5.58238	0.00015	0.849911
11	17.84091	15.16312	0.00136	0.849872
12	18.87136	16.03919	0.00036	0.849913
13	14.95666	12.71182	0.00027	0.849902
Average..				0.849906

The average ratio is slightly lower than that previously found by Baxter, 0.849943. When combined with the ratio of silver to iodine pentoxide determined by Baxter and Tilley, 0.646230, the percentage of iodine in iodine pentoxide is found to be 76.0355 and the atomic weights of iodine and silver to be 126.913 and 107.864, respectively. This value for the atomic weight of silver is in very close agreement with that recently found by Richards and Willard through the analysis of lithium perchlorate, 107.871. This investigation will be published in the Journal of the American Chemical Society, vol. 32, December, 1910.

In order to confirm the results of this research, further experiments upon the ratio of the atomic weights of iodine and silver will be made by the conversion of silver iodide into silver chloride.

The analysis of phosphorus tribromide was continued by Dr. C. J. Moore. (See Year Books Nos. 7 and 8.) This substance was prepared by allowing pure dry bromine to react with pure dry phosphorus in a vacuum. The chief difficulty in preparing the tribromide lay in the removal of the pentabromide formed by the excess of bromine which was necessarily added; for to use a deficiency of bromine was found impossible, since under these circumstances either a lower bromide of phosphorus is produced which evaporates with the tribromide, or else the phosphorus itself dissolves in the tribromide and distils with it. For the same reason it was not feasible to remove the pentabromide by distillation from either red phosphorus or metallic silver. Finally it was found necessary to eliminate the pentabromide by simple distillation in a vacuum. During the distillation the pentabromide dissociates into tribromide and bromine, and the bromine is eliminated in the first fractions of distillate. Even if it is not possible to remove the excess of bromine completely in this way, the distilled material will at any rate yield a minimum value for the atomic weight of phosphorus. The tribromide was not exposed to air or moisture at any point in its preparation. It was collected by distillation into small glass bulbs sealed off while exhausted.

Several specimens of the tribromide have been prepared and have been analyzed volumetrically by first decomposing the tribromide with water and then titrating the hydrobromic acid produced against equivalent amounts of silver, and gravimetrically by the determination of the silver bromide formed. Owing to the reducing effect upon the silver salts by the phosphorous acid formed in the decomposition of the tribromide with water, it was necessary to oxidize the phosphorous acid by means of hydrogen dioxide, first in ammoniacal solution and then in dilute nitric acid solution, before the precipitation of the silver bromide. The material prepared and analyzed in this way indicates the value for the atomic weight of phosphorus 31.03 (Ag = 107.870), which is identical with the value obtained by Baxter and Jones from the analysis of trisilver phosphate.

The investigation upon neodymium chloride which was carried on last year by Dr. H. C. Chapin (see Year Book No. 8) has been completed by the determination of the moisture in neodymium chloride dried as for analysis,

by the determination of the specific gravity of neodymium chloride, and by the examination of the absorption spectrum of aqueous solutions of neodymium salts both in the visible and in the ultra-violet regions. The percentage of moisture in the dried salt was found to be very small, 0.003 per cent, and lowers the values for the atomic weight of neodymium given in the previous Year Book by only eight one-thousandths of a unit. The specific gravity of the fused salt at 25° referred to water at 4° was found to be 4.134, while Matignon's value, which was used in the previous calculations, is 4.18. In the following table are given the final corrected values for the different samples of neodymium chloride, based upon the atomic weight of silver 107.870. This investigation has been published in the Proceedings of the American Academy of Arts and Sciences, vol. 46, 215–244, 1910.

Sample.	Percentage of praseodymium.	Atomic weight of neodymium.	Atomic weight of neodymium corrected for praseodymium.
A	0.2	144.252	144.260
B	0.15	144.265	144.271
1+2	0.0	144.275	144.275
4+5+6	0.0	144.251	144.251
10+11	0.0	144.260	144.260
14+15	0.1	144.251	144.255

Mr. T. Thorvaldson continued the investigation upon the atomic weight of iron begun in the previous year by Mr. Cobb. In this investigation ferrous bromide was analyzed in the way commonly employed in this laboratory by titration against an equivalent amount of silver and gravimetrically by collecting the silver bromide produced.

The ferrous bromide was formed by the solution of very pure metallic iron in aqueous hydrobromic acid and crystallization of the salt from hydrobromic-acid solution. The metallic iron was a specimen of material obtained from the American Rolling Mills Company. It contained the following impurities: sulphur 0.19 per cent, phosphorus 0.003 per cent, carbon 0.018 per cent, copper 0.05 per cent, manganese trace, and silicon trace. It was purified by solution in nitric acid, and double precipitation as hydroxide with pure ammonia, with solution in nitric acid in the first case, but in sulphuric acid in the second; electrolytic reduction to ferrous sulphate; electrolytic deposition from oxalate solution on a platinum dish; solution in nitric acid and crystallization of the nitrate; ignition of the nitrate to oxide, and reduction to metal in a stream of pure hydrogen.

The ferrous bromide was first dehydrated and then fused in a weighed quartz boat in a current of nitrogen which had been saturated with hydrobromic-acid gas by passing through fuming hydrobromic-acid solution. The salt was dissolved in slightly acidulated water, and before precipitation with the silver-nitrate solution it was oxidized with a slight deficiency of potassium dichromate.

A second sample of material was prepared from meteoric iron. Nickel was the chief impurity contained, the greater part of which was eliminated as sulphide and the remainder by precipitating the ferric hydroxide many times with a large excess of ammonia, as previously described. Metallic iron was obtained by processes similar to those enumerated above.

Eighteen titrations against silver with the first sample of material yielded as an average value for the atomic weight of iron 55.835 (Ag = 107.870), while 16 gravimetric analyses gave an average value 55.831. In the case of the meteoric material 5 titrations gave as an average result 55.829 and 5 gravimetric determinations 55.827; 4 of the analyses with the meteoric material were, however, subject to slight uncertainty. The 6 analyses which were free from known error gave an average value 55.832.

The difference between the results with the two samples is no greater than the probable experimental error, and therefore there can be no doubt that the two specimens of material were identical. The final result for the atomic weight of iron is less than one one-hundredth of a unit lower than the value previously obtained by Baxter with ferrous bromide which had been sublimed in porcelain tubes and which was found to contain a small quantity of alkali bromides extracted from the tubes. This investigation will be published very shortly.

The investigation upon lead bromide begun by Mr. Worsham (see Year Book No. 8) was continued by Mr. Thorvaldson. The previous difficulty in obtaining fused lead bromide which would dissolve completely in water was apparently due to hydrolysis of the salt during solution, with the formation of an insoluble basic bromide. Hydrolysis was prevented by adding a small amount of acetic acid to the water in which the salt was dissolved. Several preliminary experiments with material fused in a current of nitrogen and hydrobromic-acid gases and analyzed as described above in the case of iron, indicate a value somewhat higher than that previously obtained by Baxter and Wilson. This investigation will be continued.

Mr. G. W. Harris undertook the determination of the atomic weight of arsenic by the titration of arsenious oxide against iodine. The method consisted in subliming recrystallized arsenic trioxide in a current of dry gas into a weighed glass tube. After the solution of the trioxide in dilute sodium hydroxide in a vacuum to prevent oxidation by the air, and after neutralization of the excess of sodium hydroxide with phosphoric acid, a weighed very nearly equivalent amount of pure iodine, which also had been sublimed in a current of dry air into a weighed tube, was dissolved in the arsenite solution. The end-point was found in the presence of starch by adding very dilute iodine or arsenite solution, with due observance of the precautions to preserve neutrality during the titration by means of soluble phosphates, which have been shown by Washburn to be necessary.

Arsenic trioxide sublimed in air yields a value for the atomic weight of arsenic of 74.96, referred to silver (107.870) and iodine (126.920), while

material sublimed in oxygen yields a somewhat higher value, 75.04. Material sublimed in nitrogen nearly free from air yields a minimum value, 74.95, which is identical with that found by Baxter and Coffin through the analysis of silver arsenate. The meaning of these variations will be further investigated and the titration of arsenic trioxide against iodine pentoxide also will be undertaken.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. Grant No. 624. *Investigations on the absorption spectra of solutions.* (For previous reports see Year Books Nos. 2–8.) $1,200

The work during the year has been on three problems: first, the nature of the solvent as affecting the absorption; second, the effect of adding free acids to salts on the absorption; third, the effect of temperature on the absorbing power of solutions.

The first problem was studied rather fully, on account of its bearing on the theory of solvation or combination of solvent with the dissolved substance. If solvents in general combine with substances dissolved in them, then the different solvates formed by the different solvents ought to absorb different wave-lengths of light. That this is true will be seen at once if we recall that the absorption of light is a resonance phenomenon. Those wave-lengths of light that are absorbed throw something in solution into resonance with themselves and are consequently stopped. The different solvates formed in the different solvents would have different compositions, and the vibrators in the molecules, whatever they are, would, consequently, be expected to have different resonance. In a word, the different non-absorbing solvents would be expected to affect the absorption of a salt dissolved in them.

One case was found by Jones and Anderson. Neodymium chloride, when dissolved in water, has a very different absorption spectrum than when dissolved in alcohol. In a mixture of water and alcohol the water-bands and the alcohol-bands coexist on the spectrogram; showing that the one set of bands was not the other set shifted in position, but that there were two separate sets of bands corresponding to the two solvents. A fairly large number of cases illustrating this same point have been found. Uranyl and uranous salts have fine absorption lines and bands, which can be carefully studied and their wave-lengths accurately measured. When a given uranyl or uranous salt was dissolved in different solvents, the resulting absorption spectra were very different. The solvents used were water, methyl alcohol, ethyl alcohol, acetone, and glycerol. The existence of water-bands, alcohol-bands, acetone-bands, and glycerol-bands has been proved.

This result is specially interesting, as it furnished another line of evidence. added to the many already discovered, for the correctness of the solvate theory.

The study of the second problem has led to results that seem to have a bearing on the nature of chemical reactions in general. It is usually sup-

posed that when a salt, say a sulphate, is treated with an acid, say nitric acid, that a part of the sulphate is transformed into nitrate, the amount depending on the amount of nitric acid present relative to the amount of salt. As the amount of nitric acid is increased the amount of the sulphate would gradually decrease until, when a large excess of nitric acid is present, practically all of the sulphate would be transformed into nitrate. The results obtained in this part of the spectrum work would indicate that the above conclusions are not correct. The nitrates of certain metals, notably of uranium, have a different spectrum from the sulphates, acetates, etc. If when uranyl nitrate was treated with sulphuric acid a part of the nitrate was transformed directly into sulphate, both the nitrate and the sulphate bands would be found upon the spectrogram. If only a small amount of sulphuric acid were added to the nitrate there would be only a small amount of the nitrate transformed into sulphate. Consequently, the nitrate bands would come out relatively strong and the sulphate bands relatively weak. As the amount of sulphuric acid present was increased, more and more of the nitrate would be transformed. The nitrate bands would, consequently, become weaker and weaker and the sulphate bands stronger and stronger, until finally practically only the sulphate bands would be present. The facts are directly at variance with these predictions.

When uranyl nitrate is treated with a relatively small amount of sulphuric acid, there is in the resulting spectrogram neither nitrate-bands nor sulphate-bands, but *bands intermediate in position between the two.* By the addition of more or less sulphuric acid these bands can be made to *occupy any position between those of the nitrate and those of the sulphate.*

Work on the absorption spectra of solutions, which has now been extended to about 5,000 solutions, shows that any given absorption bands are characteristic of a given chemical condition. Indeed, this seems to hold about as well for the absorption spectra of solutions as for the emission spectra of the elements. This being the case, the conclusion is forced upon us that between the nitrate and the sulphate there is a whole series of systems or compounds, for the most part too unstable to isolate, yet existing in solution, as is shown by their action on light. These may be sulphonitrates or nitrosulphates; this question can not be answered at present, because these systems or compounds are too unstable to isolate chemically. The chemical equations used to express chemical reactions do not take into account these intermediate systems. As is well known, these equations express only the beginning and the end of chemical reactions and do not take into account the intermediate stages.

A sufficiently large number of examples illustrating the above point have been brought to light to justify drawing some conclusion with reference to chemical reactions in general. This *gradual change* in the position of the bands has been noted when uranyl nitrate is treated with sulphuric acid, with hydrochloric acid, or with acetic acid. It has also been found when uranyl and uranous acetates are treated with various acids, and when uranous and

neodymium salts are treated with nitric acid; the salts and acids studied having been selected so as to show the greatest spectroscopic changes when one salt is transformed into another.

Since these reactions do not differ chemically from reactions in general, it is a fair question to ask at least *whether chemical reactions in general are not more complex than are represented by our ordinary equations?* It is difficult, not to say impossible, to see why these intermediate systems should be formed in the reactions studied spectroscopically if they are not also formed in other chemical reactions. This suggestion seems all the more probable in that there are certain lines of evidence, from the chemical side, pointing to the existence of intermediate compounds in chemical reactions.

In studying the third problem—the effect of temperature on the absorption of light by solution—a thick-walled steel tube closed at both ends with glass or quartz plates and lined on the inside with gold was employed. Tubes of different lengths were used for solutions of different concentrations. Considerable difficulty has been experienced in closing the apparatus to withstand high pressure, yet it has been possible to work with alcoholic solutions and with mixtures of alcohol and water at temperatures well above the boiling-point of alcohol.

Although work on this problem can be said to be only fairly begun, some results of interest have already been obtained. The effect of rise in temperature is, in general, to cause the absorption bands to widen, a few exceptions, however, having been found.

Solutions that show both the water-bands and alcohol-bands with equal intensity at ordinary temperatures show these bands to have very unequal intensities when the temperature is raised. Of the solutions studied the alcohol-bands are the more persistent at the elevated temperatures, indicating that the alcoholates undergo less change in composition with rise in temperature than the hydrates.

The effect of temperature on the absorption spectra of solutions will be extended next year to as high temperatures as may prove to be possible.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. Grant No. 614. *Study of the measurement of the osmotic pressure of solutions.* (For previous reports see Year Books Nos. 2–8.) $1,800

The purpose of the work of the past year, as of that of the previous year, has been to determine with all possible certainty the relation of osmotic pressure to temperature. As the method of measurement has been improved from time to time, and as the results which should agree have become more concordant in consequence of the removal of known sources of error, it has been found that the ratios of osmotic to calculated gas pressure at different low temperatures has approached a constant value for any given concentration of cane-sugar solution. In other words, the later results indicated an increasingly closer agreement between the temperature coefficients of osmotic and gas pressure, *i. e.*, that osmotic pressure obeys the law of Gay-Lussac for gases.

To test this apparent agreement—or, rather, to ascertain beyond a reasonable doubt the temperature coefficient of osmotic pressure—very elaborate arrangements were made to meet and minimize the remaining known defects of the method. The improvements made concerned every phase of the work and in many cases were of a fundamental character. The cells were improved in a number of important particulars. The automatic system of temperature regulation was advantageously modified. The older baths were reconstructed in order to introduce the numerous improvements which long experience with them had shown to be necessary or desirable. Three new baths were built, which made it practicable to deposit the membranes—and to maintain the cells at all times when out of use—at the temperatures at which measurements were to be made. Another bath was constructed for measuring pressure at high temperatures. The largest single source of error in the work at present appears to be the manometers; accordingly the facilities for the calibration and verification of these instruments were increased and greatly improved. The above will serve to indicate the thoroughgoing nature of the preparation for the solution of the problem in hand. The essential details will be given in a series of papers about to appear in the American Chemical Journal.

The results of the actual measurements made under the improved conditions are given below in tabular form, except in so far as they have not yet been verified by duplicate determinations. At all points where verification is still lacking the spaces have been left vacant. The table gives the pressures obtained and the ratios of these to the calculated gas-pressure of the material in solution. It is to be noted that all solutions employed in this work are made by dissolving the appropriate weight of material in 1000 grams of water. Comparing the ratios of osmotic to gas pressure, it will be seen that between 0° and 25° they are very constant for any given concentration.

The Osmotic Pressure of Cane-sugar Solutions.

Weight, normal concentration.	Osmotic pressure in atmospheres.						Ratio of osmotic pressure to gas pressure.					
	0°	5°	10°	15°	20°	25°	0°	5°	10°	15°	20°	25°
0.1	.....	2.452	2.498	.....	2.590	2.636	.....	1.081	1.082	.....	1.0835	1.081
0.2	4.722	4.818	4.893	.....	5.961	5.148	1.061	1.063	1.060	.....	1.059	1.059
0.3	7.085	7.198	.....	.....	7.605	7.727	1.061	1.058	.....	.....	1.061	1.060
0.4	9.422	9.608	9.790	.....	10.137	10.296	1.060	1.059	1.060	....	1.060	1.059
0.5	11.895	12.098	12.297	.....	12.748	12.951	1.068	1.067	1.066	.....	1.067	1.066
0.6	14.381	14.605	14.855	15.131	15.388	15.624	1.0765	1.074	1.073	1.074	1.073	1.071
0.7	16.886	17.206	17.503	17.821	18.128	18.435	1.083	1.084	1.083	1.084	1.084	1.083
0.8	19.476	19.822	20.161	20.533	20.906	21.254	1.093	1.003	1.092	1.093	1.095	1.092
0.9	22.118	22.478	22.884	23.314	23.715	24.126	1.104	1.102	1.102	1.103	1.103	1.103
1.0	24.825	25.283	25.680	26.189	26.648	27.053	1.115	1.115	1.113	1.115	1.115	1.113

The relation of osmotic pressure to temperature is established in the field covered by the work with much greater certainty than the relation of pressure to concentration, the reason being that the undeterminable and unknown errors of the manometers are of much less importance in the former than the latter case. The results given in the table have not hitherto been published.

The writer has been assisted, in the investigations here reported, by Drs. W. W. Holland and E. G. Zies and Messrs. W. M. Clark and C. N. Myers.

Noyes, Arthur A., Massachusetts Institute of Technology, Boston, Massachusetts. Grant No. 625. *Researches upon the physical properties of aqueous solutions in relation to the ionic theory.* (For previous reports see Year Books Nos. 2–8.) $3,000

During the past year the several lines of investigation described in previous reports have been continued. It may be recalled that the general object of these researches is to develop the Ionic Theory of Solutions, or at any rate the empirical principles expressing the phenomena involved, in such a way as to account for the unexplained anomalies which aqueous solutions of strong electrolytes exhibit.

The special subjects that have been under investigation are: (1) the transference numbers of tri-ionic salts (especially of thallous sulphate and lead nitrate), by Dr. K. G. Falk, with the purpose of determining whether intermediate ions, such as $TlSO_4^-$ or $PbNO_3^+$, exist in considerable quantity; (2) the electrical conductivity of mixtures of salts, by Mr. A. C. Melcher, Dr. W. C. Bray, and Mr. F. L. Hunt, with the purpose of establishing the general law governing the ionization of salts; and (3) the solubility of salts in the presence of other salts, by Dr. W. D. Harkins, with the purpose of determining empirically the form of the law of solubility-effect which must be substituted for the inexact mass-action form of that law.

A systematic, critical review of existing data bearing on the properties of solutions in their relations to the Ionic Theory has also been begun with the aid of Dr. K. G. Falk; and a first paper of the series, dealing with freezing-point lowerings, has already been published (Jour. Amer. Chem. Soc., vol. 32, pp. 1011–1030).

During the past year articles describing the work previously completed and reported on in earlier volumes of this Year Book have also been published as follows:

(1) The solubility of silver chloride, barium sulphate, and calcium sulphate at high temperatures, by A. C. Melcher (Jour. Amer. Chem. Soc., vol. 32, pp. 50–66).
(2) The hydrolysis of ammonium acetate and the ionization of water at high temperatures, by A. A. Noyes, Yogoro Kato, and R. B. Sosman (Jour. Amer. Chem. Soc., vol. 32, pp. 159–178).
(3) The ionization of salts in mixtures with no common ion, by M. S. Sherrill (Jour. Amer. Chem. Soc., vol. 32, pp. 741–748).

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. Grants Nos. 524, 570, and 626. *Extended investigations of precise values of atomic weights; and a study of volume and energy relative to material in relation to the new hypothesis of compressible atoms.* (For previous reports see Year Books Nos. 2–8.) Each grant, $2,500

(1) *The Revision of the Atomic Weight of Calcium:*

With the help of Dr. Otto Hönigschmid, upon leave of absence from the Royal German University of Prague, a careful research was completed upon the atomic weight of calcium. This element is especially interesting, not only because it is one of the very common and important constituents of the surface of the globe, but also because it is one of the interesting series of which radium is the last and newest member. The atomic weights of barium and strontium, the other members of this series, have been determined with care in the Chemical Laboratory of Harvard College, and that of calcium was begun 15 years ago, but only preliminary determinations were made at that time. It was very highly desirable, therefore, to complete this work. Dr. Hönigschmid analyzed with great care many pure specimens of calcium bromide and chloride made in different ways from the purest materials, with all the precautions recently devised in this laboratory, and obtained the following final average results, if silver is given the present international value, 107.88:

From the ratio $2Ag:CaBr_2$ (6 analyses)	Ca=40.070
ratio $2AgBr:CaBr_2$ (6 analyses)	Ca=40.070
ratio $2Ag:CaCl_2$ (7 analyses)	Ca=40.074
Average of 19 analyses	Ca=40.071

Not only the averages, but also the individual results, agreed very closely with one another.

The outcome leaves no doubt that the atomic weight of calcium is not far from 40.07, a result only slightly lower than that given by the preliminary Harvard investigations (40.08), but much lower than the value, 40.15, obtained by Hinricsen under Landolt's direction in Berlin.

This work will appear among the publications of the Imperial and Royal Academy of Sciences of Vienna as well as in the usual American publications.

(2) *The Revision of the Atomic Weights of Lithium, Chlorine, and Silver:*

This investigation, concerning which a comprehensive paper was published in Publication No. 125 of the Carnegie Institution of Washington and reprinted in the Journal of the American Chemical Society and the Zeitschrift für Anorganische Chemie, has been continued yet further during the present summer, Dr. H. H. Willard having returned to Harvard from the University of Michigan for the summer months on this account. The work is being conducted with the yet greater precision made possible by experience gained in the work already published, and the operations are being conducted upon a somewhat larger scale. The earlier results are confirmed. Evidence is to

be obtained also concerning the possible retention of traces of water in the lithium perchlorate which serves as one of the standard substances.

(3) *Adiabatic Determination of the Heats of Solution of Metals in Acids:*

During the winter of 1908–09, with the help of Dr. L. L. Burgess, the heat evolved by the action of the more electropositive among the heavy metals upon acids was studied with great care, the object being to secure precise data for thermochemical and thermodynamic computation. These experiments have already been described in the report of last year, and in greater detail in a paper published in the Journal of the American Chemical Society. In the course of the work it was shown that much greater accuracy in the determination of the heats of dilution of the acid solutions concerned was needed than had been supposed to be necessary in the past. It was shown that Thomsen's method of applying the heat of dilution to the results was wholly erroneous, and preliminary results for the heat of dilution of the liquids concerned were obtained. Before publishing this latter part of the work it seemed highly desirable, however, to obtain more accurate knowledge concerning these quantities; and during the winter of 1909–10 a protracted series of very careful experiments was made with a new, more accurate thermometer, by Dr. Allen W. Rowe. These not only fix beyond question the heat of dilutions of several strengths of hydrochloric acid, but show the interesting fact that zinc chloride, when substituted in small amount for its equivalent quantity of acid, considerably increases the heat of dilution of the acid, whereas cadmium chloride diminishes it. The full details are described in a comprehensive paper which has already been sent to the press. This paper will appear in the Journal of the American Chemical Society and will ultimately be published, it is hoped, among the publications of the Carnegie Institution of Washington in a volume including all the recent thermochemical studies carried out at Harvard University.

(4) *The Heat of Neutralization of Strong Acids and Strong Bases:*

This problem, undertaken with the help of Dr. Rowe and discussed in the last report, has been studied further during the year just past. Confirmatory results obtained in several different ways and with different thermometers have made the outcome so certain that the results are now practically ready for publication.

(5) *The Specific Heats of Aqueous Solutions:*

The method already described in the previous report has been improved so that results of very great constancy and reliability can now be obtained with a minimum of exertion. During the past winter the specific heats of solutions of hydrochloric, hydrobromic, hydriodic, nitric, and perchloric acids, as well as sodium and potassium hydroxides, have been obtained with Dr. Rowe's assistance. The hydroxide of lithium is now being investigated. Interesting relations have already been detected from the comparison of the data for analogous substances.

(6) *The Heat of Combustion of Pure Organic Substances:*

Concerning this subject a comprehensive investigation completed last year with the help of Dr. R. H. Jesse, jr., was discussed in the last report and has since been published in full. This research is now being continued with the assistance of Mr. F. Barry; and the novel apparatus and methods used in the previous work have continued to yield admirably consistent results. The data already secured, together with those to be obtained in the future, will, it is hoped, form a more satisfactory basis for the comparison of the internal energy-changes of these substances than any other data thus far available.

(7) *The Compressibility of Ice:*

In the last report it was pointed out that the compressibility of ice is a datum of much interest, and the execution of a preliminary determination was announced. During the past winter, with the assistance of Prof. C. L. Speyers, this matter has been carried much further, and the quantity in question has been determined with considerable accuracy. According to one method, the compressibility of ice at —7° C. was found to be 0.0000118, and according to another 0.0000116, between 100 and 500 megabars, if the compressibility of mercury under like conditions is taken as 0.0000037. The outcome is surprising. One might have expected the compressibility of ice to be greater than that of water, since as a general rule the phase of any given substance possessing the greater volume has also greater compressibility. Thus the substance water forms an exception in this respect, as in so many others, to the general rules usually governing the physical properties of solid and liquid substances.

(8) *The Surface-Tensions of Liquid Substances:*

In connection with the comprehensive research upon the compressibility of liquids discussed in a previous report, Professor Speyers has also determined the surface-tensions of liquid substances; because compressibility has been shown by Richards and Mathews, as well as by other investigators, to be fundamentally connected with surface-tension. In the course of this new work upon surface-tension it has been found that many previous investigations have been inadequate because of the still remaining slight "capillary" effect of the walls of even fairly wide containing-vessels. As a rule, in the past, experimenters have not used vessels nearly wide enough to eliminate this source of error. The careful study of the surface-tension of a number of liquids whose compressibilities have also been determined at different temperatures and in tubes of different sizes promises to throw light upon the whole subject, including the relation between surface-tension and compressibility.

It has already been pointed out that many of these investigations are already in print or in press. References to these will be found in the Bibliography of this Year Book (page 51). The others will be cast into shape suitable for publication as soon as circumstances will permit.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. Grant No. 571.
Study of fundamental problems of geology. (For previous reports see Year Books Nos. 2–8, inclusive.) $4,000

The year has been spent mainly on special inquiries bearing on the sources and the methods of supply and of depletion of atmospheric material and on the regulative factors that enter into the maintenance of the equilibrium of the atmosphere and into the limitation of its oscillations, as these are implied by the climatic data of the geologic record. A paper on the secular maintenance of the atmosphere, embodying these results, has been in course of preparation during the last quarter of the year.

Moulton, F. R., University of Chicago, Chicago, Illinois. Grant No. 627.
Continuation of investigations relating to the planetesimal hypothesis. (For previous reports see Year Books Nos. 4, 5, and 8.) $2,000

The work finished during the year and now being published or ready for publication is:

Periodic Orbits (vol. I):

For description see Year Book No. 8.

The Straight-Line Solutions of the Problem of Bodies:

In this paper it is proved that it is possible to arrange any n positive finite masses on a straight line in precisely $\frac{1}{2}\,n\,!$ different ways, so that, under proper initial projections, they will always remain collinear. The orbits of the masses are similar conic sections having the center of mass of the whole system as a focus. This is the complete generalization of Lagrange's results for the Problem of Three Bodies.

The related problem is solved of determining, when possible, n masses such that if they are placed at n arbitrary collinear points they will, under proper initial projection, always remain in a straight line. If n is even and the linear dimensions of the orbits are given, it is proved that the n masses are in general uniquely determined; and that if n is odd the coördinates of the n points must satisfy one algebraic relation, after which, choosing any one of the masses arbitrarily, the remaining $n-1$ are uniquely determined. This paper is in type for the Annals of Mathematics.

The Singularities of the Two-Body Problem for Real Initial Conditions:

From the standpoint of analysis, the most important properties of a function are the location and character of its singularities. They determine the character of its expansibility at every point. This paper makes a complete discussion for the problem of two bodies for all real initial conditions. It has been submitted to the Transactions of the American Mathematical Society for publication.

Linear Differential Equations with Periodic Coefficients:

This paper was prepared with the collaboration of Dr. W. D. MacMillan, of the University of Chicago. It takes up first in a new way the proof of the analytic character of the solutions in the general case of a simultaneous set of equations of any order. Then it treats those equations whose coefficients have the property of being expansible as power series in certain parameters, and exhibits not only the character of the solutions with respect to these parameters, but shows how actually to construct them by relatively simple and convenient processes. These are the equations which arise in celestial mechanics and their solutions in all cases are now at hand. The most useful cases for equations with right members are also treated. This paper is being published by the American Journal of Mathematics.

Problem of the Spherical Pendulum from the Standpoint of Periodic Orbits:

The problem of the spherical pendulum falls in the class of those which can be treated by the methods of periodic orbits. The solution of the z-equation leads to elliptic functions which are obtained here expanded as power series in their modulus directly from the second-order differential equation. The method is applicable, with slight modifications, to hyperelliptic functions. After the z-equation has been solved the x and y equations become linear of the second order with periodic coefficients which are expansible as power series in the modulus of the elliptic functions. The solutions of these equations are found. After the properties of the solutions have been derived from the original differential equations, the remarkable fact is shown that all the coefficients can be obtained from the integral relations which hold among the coördinates. Thus a second independent method of computing them is given. This paper is being submitted to the Rendiconti di Palermo for publication.

A Certain Class of Oscillating Satellites:

In this paper two finite masses are supposed to be describing undisturbed elliptical orbits, and an infinitesimal mass is moving near one of the Lagrangian centers of libration. The conditions under which its oscillations can be periodic are determined, and a method of finding these solutions is given. The coördinates are expansible as sums of fractions of a parameter, of which they are discontinuous functions.

The work under preparation is:

The first three subjects described in Year Book No. 8, p. 225.
Continuation of the work on periodic orbits for a second volume.
The section on cosmogony for Encyclopædie der Mathematische Wissenschaften.

GEOPHYSICAL RESEARCH.

Adams, F. D., McGill University, Montreal, Canada. Grant No. 503. *Continuation of investigation into the flow of rocks.* (For previous reports see Year Books Nos. 2–7.) $1,500

This investigation is now nearly completed. During the past year a study of the effect of deformation on the strength of compact and more or less impure limestones was completed. Solenhofen lithographic stone and black Belgian limestone ("Noir fin") were selected, and it was found that even at the ordinary temperature, under differential pressure, they can be deformed without loss of strength. It is evident from these and from the experiments of former years that limestones of any kind, pure or impure, may in the folding of the earth's crust be contorted without losing strength during the process. An extended series of experiments has also been carried out on the deformation of granite, diabase, and essexite at temperatures ranging from the ordinary temperature of the laboratory up to 1000° C. The temperatures chiefly employed, however, were 450° C. and 550° C. In these experiments a modification of the method described was adopted with very satisfactory results. This consists in deforming those hard Plutonic rocks in the form of disks which are placed between disks of marble, the whole being then inclosed in steel in the usual manner. It is found that the marble effects a distribution of the pressure upon the flowing disk of granite or diabase which it was impossible to secure under the older method. The rocks in question, as well as the essexite, developed a very perfect Cataclastic structure under the movement, but remain hard and compact. A series of experiments has been made to determine what proportion of their strength they retain after deformation at the ordinary temperature and at a temperature of 450° C.

Another investigation, referred to in a former report, has also been continued. This deals with the pressures required to cause small holes bored through columns of limestone or granite to close, the rocks being inclosed in very heavy tubes of steel, so that this can not become deformed in the usual manner. These are developing results of considerable interest. Two preliminary papers presenting some of the results obtained have appeared during the past summer and others will be published within the next few months. The titles of the two papers are as follows:

An experimental investigation into the flow of rocks. First paper. The flow of marble. (Amer. Jour. of Science, June 1910.)

An experimental investigation into the action of differential pressure on certain minerals and rocks, employing the process suggested by Professor Kick. (Jour. of Geology, Sept.–Oct., 1910.)

LITERATURE.

Sommer, H. Oskar, Astolat, Camberley, Surrey, England. Grant No. 650. *Completion for publication of results of researches on Arthurian Romances.* (For previous reports see Year Books Nos. 5–8.) $3,000

1. I have transcribed at the British Museum the additional manuscript 10294, representing the sixth volume of the Vulgate Version of the Arthurian Romances. I have collated the text with the other manuscript at the British Museum, and with the photographic reproduction of the manuscript No. 342 of the Bibliothèque Nationale. The photographs being of reduced size, this task had to be performed by the help of a magnifying glass, and was of a very trying nature, occupying ten weeks.

2. I have revised the pages of volume III for the second time and completed the volume for publication.

3. I have revised for the first time the remaining galleys of volume IV.

4. I have revised for the first time the whole of the fifth volume and made it ready for making up in page form.

The following work remains to be done:

1. The second revise of the whole of volumes IV and V and the addition of head-lines and side-notes.

2. The first and second revises of volume VI and the addition of head-lines and side-notes.

3. The compilation of the Index raisonné to the six volumes.

METEOROLOGY.

Bjerknes, V., University of Christiania, Christiania, Norway. Grant No. 610. *Preparation of a scientific work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–8.) $1,200

The working out of the kinematic methods for investigating and representing synoptically the atmospheric or oceanic motions has been finished. The final examples of the synoptic representation of fields of motion in the atmosphere have been worked out, and the text is nearly ready. The reading of the proof-sheets of the meteorological and the hydrographic tables has been continued, and the tables entirely revised and brought up to date according to the newest determinations of the fundamental constants.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. Grant No. 558. *The application of Cremona groups to the solution of algebraic equations.* $1,000

Professor Morley reports that a memoir by Prof. A. B. Coble, called "The reduction of a sextic equation to the Valentiner Form-problem," has been accepted by Professor Klein and will appear in the Mathematische Annalen. This bears directly on the subject of the grant, and a further memoir by Dr. Coble will be submitted later.

A memoir by Dr. J. R. Conner, on "The norm-curve in four dimensions," is completed. This was a matter taken up in connection with the proposed problem.

NUTRITION.

Osborne, T. B., Connecticut Agricultural Experiment Station, New Haven, Conn. Grant No. 573. *Comparative study of the more important vegetable proteins.* (For previous reports see Year Books Nos. 3–8.) $5,000

Grant 573 ($5,000).—A large part of the work done under this grant has been directed to determine the nature of the deficit shown by even the most successful protein analyses. It has been found that a large part of this deficit is caused by defects in the analytical methods, losses occurring through incomplete hydrolysis of the protein; through secondary decompositions during the hydrolysis leading to the formation of humin; through incomplete esterification and extraction of the esters; through condensation of the esters during distillation; and through imperfect separation of the individual amino-acids by fractional crystallization. Although it has long been known that losses were thus caused, it appears that few if any realized that in the aggregate these were so large as we have found them to be.

The yield of some of the amino-acids is materially increased by longer hydrolysis, and it is necessary to boil the protein with strong acids for a very much longer time than has heretofore been the practice.

The formation of humin is almost certainly limited to secondary decomposition of histidine, tryptophane, and carbohydrate, since zein, which yields none of the latter two and only a very small amount of histidine, yields but a trace of black amorphous substance known as humin.

The losses which occur through incomplete esterification appear to be small if this process is properly conducted, but the conduct of this operation is simplified and expedited by applying a method proposed by Phelps and Phelps for esterifying organic acids. The losses incident to extracting the esters with ether can be reduced to an unimportant amount by repeating this process a sufficient number of times.

The greatest loss is caused by decomposition of the esters during distillation, whereby products of unknown nature are obtained in the higher-boiling fractions of the esters and a relatively large amount of undistillable residue is formed. These losses can be reduced to a considerable extent by distilling as rapidly as possible to a temperature sufficiently high to carry over all of the leucine ester and then treating the undistilled esters according to the method usually applied to the higher-boiling fractions. This procedure simplifies the process and materially decreases the labor involved.

The losses caused by incomplete separation of the amino-acids can be reduced to a comparatively small amount by careful work and by using the method of Levene and Van Slyke for separating leucine and a method devised for separating the dibasic glutaminic and aspartic acids from the monobasic amino-acids by aid of their acid sodium salts.

Much larger losses than have heretofore been assumed have been found to take place when alcohol or ether are distilled from the free esters and the yield, especially of alanine, can be greatly increased by taking the necessary precautions to recover it from the distillate.

The extent of these losses has been learned by making several analyses of zein and by analyzing known quantities of the amino-acids which this protein contains mixed together in the same proportion as these were obtained from this protein. By assuming the losses in the analysis of zein to be equal to those that occurred in the analysis of this mixture, it has been found that over 92 per cent of this protein almost certainly consists of those amino-acids which were previously known as its decomposition products. In making this estimate, account was taken of the water which is eliminated when the amino-acids are combined in polypeptide union.

By taking advantage of the knowledge gained in this study the total quantity of decomposition products actually isolated from zein in a pure form has been very materially increased above that earlier obtained by working under the formerly employed conditions. This is shown by a comparison of the following figures:

Analysis of Zein.

	Former analysis.	Present analysis.		Former analysis.	Present analysis.
	per cent.	*per cent.*		*per cent.*	*per cent.*
Glycocoll	0.00	0.00	Tyrosine	3.55	3.55
Alanine	2.23	9.79	Arginine	1.16	1.55
Valine	0.29	1.88	Histidine	0.43	0.82
Leucine	18.60	19.55	Lysine	0.00	0.00
Proline	6.53	9.04	Tryptophane	0.00	0.00
Phenylalanine	4.87	6.55	Ammonia	3.61	3.64
Aspartic acid	1.41	1.71	Carbohydrate	0.00	0.00
Glutaminic acid	18.28	26.17			
Serine	0.57	1.02	Total	61.53	85.27

As zein constitutes 5 per cent of the corn crop, its enormous commercial value justifies the expenditure of much time and money in learning everything possible about its constitution. The increased knowledge of its decom-

position products thus incidentally gained in this study of the analytical methods has much value apart from its application to the analysis of other proteins and is to be considered a part of an extensive investigation of the proteins of this important seed which we have already entered upon.

The results of the work above described have been published in the American Journal of Physiology, 1910, XXVI, pp. 212–228, 295–304, and 305–328; 420–425.

An extensive study of the proteins of the hemp seed has been made which is now approaching completion. This is designed to give information concerning the nature and proportion of all of the different proteins of this seed and a better knowledge of their properties. It is expected that this work will yield results of general application for the better isolation and preparation of seed proteins than has heretofore been possible and also shed light on some of those minor changes which proteins undergo and about which little is at present known. Some further work is required to make the data thus far accumulated available for publication.

During the past year extensive feeding experiments have been undertaken in cooperation with Prof. Lafayette B. Mendel, of Yale University, under a grant from the Adams fund. The purpose of this work is to study the relative nutritive value of the more important food proteins. In connection with this investigation much work has been done under this grant in preparing large quantities of proteins for feeding purposes and in obtaining more definite knowledge of the properties of some of these proteins which appeared to be of importance in connection with their food value. Valuable data have already been obtained and a part of these have been discussed in a paper which is now nearly ready for publication.

An extensive study of the anaphylaxis reaction has been begun in cooperation with Prof. H. Gideon Wells, of the University of Chicago, who has already conducted several hundred experiments on animals with very pure preparations of proteins which we have prepared for him. The results of this study are now ready for publication.

PALEONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. Grants Nos. 559 and 611. *Continuation of the work on the Permian reptiles and amphibia of North America.* (For previous reports see Year Books Nos. 2, 4, and 8.) $3,200

Professor Case has completed the preliminary manuscript of two monographs, one on the Cotylosauria and Pareiasauria of North America and one on the Amphibia and Pisces of the Permian of North America. These will average about 275 pages each and will be accompanied by about 30 plates each and numerous text figures. The manuscripts are the result of studies in American museums. Last summer Professor Case studied related forms in

European museums for comparison. The manuscript of the first monograph has been sent to the Carnegie Institution of Washington, and the second will be forwarded by December first of this year.

Wieland, G. R., Yale University, New Haven, Connecticut. Grants Nos. 628 and 648. *Continuation of investigations on fossil cycads.* (For previous reports see Year Books Nos. 2–4 and 6–8.) $2,000

The two memoirs on American fossil cycads announced in previous reports are now nearing completion. Moreover, there is in projection a further general treatise on the fossil cycadales which should form a notable contribution to our knowledge of the structure and distribution of Mesozoic plants, inasmuch as it now becomes possible to examine in new light the only two well-marked *Williamsonia* floras hitherto known, namely, those of the Yorkshire coast and the Gondwanas of India, both of which it is intended to restudy in field and laboratory.

As indicated last year, the field-work in Mexico, noted as desirable in an earlier report, resulted in the discovery of a profusion of early Mesozoic cycads, including the first series of *Williamsonia* fruits to be reported from North America. In addition to their definite stratigraphic interest, these Williamsonias of southern Mexico present a noteworthy variety of form and include the most reduced staminate disk yet discovered. As discussed tentatively in the Botanical Gazette for last December, the existence of such a flower does suggest polyphyletic origins amongst the angiosperms, and renders more plausible the ascription of certain foliar types found low down in the Cretaceous to such modern and supposedly advanced genera as *Viburnum* and *Nerium*. Indeed, this new evidence, taken in conjunction with the recent discovery of Nathorst that the Rhätic cycad *Wielandiella* had monantherous microsporophylls as minute as stamens, goes far toward a demonstration of the validity of our theory of angiosperm origin by reduction.

These complementary studies of *Williamsonia* floras having been brought thus far forward, active work on the silicified cycads has been resumed, and is now so far advanced that the companion volume to American Fossil Cycads (structure), or that in taxonomy, should be ready to submit for publication during this coming year. As already announced, the results will have more than a merely taxonomic interest, the floral structure of some little-known species having been found to exhibit more variety than was at first anticipated.

Many additional thin sections of the largest size have been cut. A notable one traverses the lateral armor of a trunk tangentially so as to bring to view no less than 17 strobili in two series about equal in number, the one large with seeds containing proembryos, and a much smaller ovulate series. This latter, in case it should prove young, would show my suggestion that the fossil cycads were more or less monocarpic to require modification. However, the corresponding series of parallel longitudinal sections has been made and it is expected that by comparative study of supplementary series from

other trunks the true condition may be exactly determined, whether indicating simply the bisporangiate or else dicœcious fruits of two seasons of fructification or, as the remaining alternative, a more or less distinct monœcious monocarpy. In any case it is once more brought forcefully home to us that the study of the young fruits yields much of interest, and that in dealing with fossil cycads every phase of angiospermous sporophyll arrangement may sooner or later be found repeated.

In these later studies the seeds have been receiving the special study merited by their morphologic interest and value as pointed out in the prefatory note to the volume in structure—the avowed effort, despite the labor involved, being to exhaust the possibilities afforded by the collections for such study, either direct or comparative. It is of primary interest to note that here, for the first time in the case of any fossil plant, the cotyledonary bundle pattern has been determined. Intermediate in form to that of the existing cycads and *Ginkgo,* it exhibits a degree of reduction not equaling that of the conifers, but showing a remarkable similarity to the more primitive of the angiosperms in the lateral strand elimination and entire form; whence we derive yet another of the cumulative proofs that Cycadeoidean fructification indicates in all larger outlines the true manner of angiosperm evolution. Taken in entirety, the series of sections demonstrating these facts of fundamental interest must without any qualification be the most complete ever worked out and brought together to illustrate genera, species differentiation, and fructification in a group of extinct plants.

Early persuaded of the interest of the cycadophytes from every scientific point of view, persistent effort has been made to carry their study beyond the boundaries of countries and the far severer limits of existing collections. The task is to link together the really little-understood silicified trunks, *Williamsonia* fruits, and ubiquitous cycad foliage of the Mesozoic, as far as may be, into a connected whole which can yield its full quota of stratigraphic and structural interest and fact.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. Grant No. 630. *Continuation of study of the properties of condensation nuclei, including ions.* (For previous reports see Year Books Nos. 4, 5, 7, and 8.) $500

In connection with his work on the coronas as a means for the study of nucleation, Professor Barus came across a principle of interferometry which seemed of sufficient importance to justify special investigation. This has been done and what appears to be a very promising new procedure in interferometry has been developed. The report is nearly ready for publication.

The method consists in bringing to interference two complete diffraction spectra (components) from the same source of light. This may be done in a variety of ways, either directly or by using the devices of Jamin, Michelson, and others for separating the components.

In the direct method, a mirror immediately behind the grating returns the reflected-diffracted and diffracted-reflected component rays, to be superimposed for interference, producing a series of phenomena which in addition to their great beauty are eminently useful. In fact, the interferometer so constructed needs but ordinary plate-glass and replica-gratings. It gives equidistant fringes, rigorously straight, and their distance apart and inclination are thus measurable by ocular micrometry. The fringes are duplex in character and an adjustment may be made whereby ten small fringes occupy the same space in the field as one large fringe, so that sudden expansions within the limits of the large fringe (as, for instance, in magneto-striction) are determinable. This has not been feasible heretofore. Lengths and small angles (seconds of arc) are thus both made subject to micrometric measurement. Finally, the interferences are very easily produced and are strong with white light, while the spectrum-line used may be kept in the field as a stationary landmark. The limiting sensitiveness is half the wave-length of light.

Professor Barus, assisted by Mr. M. Barus, has worked out the theory, has devised advantageous instrumental equipment, and has made a number of incidental applications to test the apparatus.

The range of measurement of such an instrument is necessarily limited to about 1 cm. and the component rays are not separated. To increase the range indefinitely and to separate the component rays, let the grating replace the symmetrically oblique transparent mirror of the Michelson adjustment, for instance. In this way transmitted-diffracted and reflected-diffracted spectra, or two corresponding diffracted spectra returned by the opaque mirrors, may be brought to interference. In the former, but particularly in the latter case, the author has been strikingly successful. The interference pattern, however, is now of the ring type, extending throughout the whole spectrum from red to violet, with the fixed spectrum-lines simultaneously in view. These rings closely resemble confocal ellipses; their centers have the same position in all orders of spectra, but the major axes of the ellipses are liable to be vertical in the first and horizontal in all the higher orders of spectra. Again, there is an opportunity for coarse and fine measurement, inasmuch as the rings have the usual sensitive radial motion as the virtual air-space increases or decreases, while the centers simultaneously drift as a whole across the fixed lines of the spectrum, from the red to the violet end. Drift and radial motion may be regulated in any ratio, and this is one advantage of the method.

Professor Barus shows that three groups, each comprising a variety of interferences, are possible, and has worked out the theory of the phenomenon and the instrumental conditions for efficient practical work. Transparent silvered surfaces are superfluous, as the ellipses are sufficiently strong not to need accessory treatment. Considerable width of spectrum-slit is also admissible. Finally, the ellipses may be made of any size and the sensitiveness of their lateral motion may be regulated to any degree by the aid of a compensator. In this adjustment the drift may be made even more delicate than the radial motion, thus constituting an entirely new method of interferometry.

Burgess, Charles F., University of Wisconsin, Madison, Wisconsin. Grant No. 560. *Investigation on electrolytic iron and iron alloys.* (For previous reports see Year Books Nos. 4–8.) $2,500

During the past year the work has been carried on under the direction of C. F. Burgess and James Aston, with the assistance of G. A. Roush and A. C. Sladky.

The electrolytic iron-refining tanks have been in operation and several hundred pounds of single-refined and double-refined iron have been produced. Practically all of this has been used in experimental work here, though some has been shipped to others investigating the properties of this material.

Continuing the work of the past, this electrolytic iron has been used as a basis for the preparation of alloys, its value lying in its comparative freedom from impurities and in its marked uniformity.

The work on alloys during the past year has been confined largely to three channels: the combined influence of copper and nickel on the strength of iron; the hardness tests of numerous alloy samples accumulated during the past few years; and the utility of electrolytic iron as a base material for the manufacture of tool steels. Among the results noted are the following: 1.5 per cent of copper addition gives a similar increase of strength as does 4 per cent of nickel. It has been found that the presence of copper is not detrimental in making nickel-iron alloys, and therefore Monel metal, a cheap source of nickel, may be used for making high-grade alloys. This conclusion has been confirmed by Mr. Clamer, who reported before the American Society for Testing Materials, in July, 1910.

Most of the results of the past year's work have been published, although some data and information still remain to be prepared for publication. A list of publications of the past year bearing upon this work will be found in the Bibliography (page 47).

Howe, H. M., Columbia University, New York, N. Y. Grant No. 618. *To determine whether the sealing of gas in blowholes of steel ingots is or is not hermetical.* (For previous reports see Year Books Nos. 6–8.) $300

In the solidification of molten or liquid substances, especially those of high melting-point, two classes of cavities are likely to form—gas-bubbles called "blowholes," and a central contraction cavity called a "pipe." The blowholes represent (*a*) the progressive concentration in the molten or liquid mother-mass of the gases initially present, a concentration carried on to supersaturation and to the liberation of part of this gas from the supersaturated layers; perhaps (*b*) and in some cases, such as that of the solidification of steel ingots, the formation of a gas from chemical reaction brought about by fall of temperature or by passage from the liquid to the solid state. In the case of steel ingots there are indications that carbonic oxide is thus formed during solidification by the union of carbon and oxygen present side by side in the molten metal.

The formation of the central "pipe" is due to the cooling and hence contraction of the different layers of the mass æoliotachically, *i. e.*, at different rates *inter se*. In the early stages of solidification the outside of the mass, especially if it is cast in a cold iron mold, cools much faster than the deeper seated solid layers. The early excess of contraction of the outside, caused by this excess of cooling, is resisted by the lagging interior, with the result that the outer layers are virtually stretched beyond their normal dimensions; so that, when solidification is complete, the interior, which in the latter part of the cooling has to cool through a greater range of temperature and hence has to contract more than the outside, no longer suffices to fill that outside completely, and this deficit of volume of the interior is represented by a central cavity, overlying the region in which the last of the solidification occurs. This same excess of contraction of the earth's crust in its early stages should later throw that crust into great compression, which may be an important element in volcanic and earthquake phenomena.

Blowholes themselves tend in effect to expand the volume of the interior as a whole, without changing its outer dimensions, and thus to lessen the deficit or pipe.

In case of steel ingots this pipe may reach very deep into the axis and, because it is hard to weld up, may compel the manufacturer to discard as much as a third of the ingot in order to get sound unpiped metal. To avoid this some makers of steel of a composition favorable to welding have purposely allowed blowholes to form rather abundantly, so as to prevent the formation of a pipe, and, relying on the ease with which such steel welds, have tried to get flawless metal by welding these blowholes up in the process of rolling the ingot out into its final form, such as that of a boiler-plate.

This procedure is of great economic importance, in that it enables the steel-maker to avoid the serious discarding which would be necessary in case his ingots were free from blowholes and hence deeply piped. But many intelligent metallurgists have condemned this practice on the ground that the closing of blowholes was impossible, because the gas which they contain must remain ever present during the rolling, even though somewhat compressed.

The present investigation seeks to learn by two lines of inquiry whether the gas of the blowholes is qualitatively absorbable, and whether the sides of the blowholes themselves are qualitatively weldable, under the conditions of actual manufacture. Both lines proceed by comparing the metal in slabs cut from the original ingot without rolling with metal cut from a boiler-plate into which that same ingot was rolled, and cut in such a way as to separate and distinguish those parts of the metal in the plate which had originally been porous when in the ingot from those which had originally been compact.

The first line showed that the enormous differences in density which existed between the porous and the compact parts of the ingot were practically completely obliterated in rolling the metal down into a boiler-plate. In one case the initial difference of 16 per cent in density was completely removed;

in the other the initial difference of 10 per cent in density was reduced to one-fiftieth its original quantity. This tended strongly to confirm the strong antecedent probability that the blowhole gases could be reabsorbed during the rolling process, thanks to its long continued great pressure at a very high temperature.

The second line of inquiry disclosed what traces of blowholes remained in the boiler-plate, by cutting very thin slices lengthwise and crosswise from that plate, mirror-polishing them, and then bending them double in such a way that any blowhole traces present ought to gape open like the cards of a bent pack. Had there been no welding of blowholes, this bending should have disclosed unwelded seams about 3.5 inches long and 1.3 inches wide. In point of fact, the traces detected were so short as to indicate strongly that a very great degree of welding had occurred, as seemed to the writer, though not to all competent investigators, to be antecedently very probable. The longest single trace was 0.07 inch long. Only one "string" of such traces was found, and this was only 0.3 inch long. Further, the scantiness of these relics of blowholes tends to show that the blowhole gases have been reabsorbed by the metal to a very great degree. Such relics of blowholes as have persisted in most cases probably represent spots where the reabsorption of the gas has become complete after the temperature has fallen too low to permit welding, and the proper course to pursue may be found in prolonging the exposure to a temperature above the welding-point, so as to complete the reabsorption of gas while the metal is still weldable.

Nichols, E. L., Cornell University, Ithaca, New York. Grant No. 631. *Continuation of researches of phosphorescence and fluorescence.* (For previous reports see Year Books Nos. 4–8, inclusive.) $3,000

The following is a brief report of the progress of the work on fluorescence and phosphorescence by Prof. Ernest Merritt and the grantee, carried on under grant No. 631 of the Carnegie Institution of Washington:

(1) *Photographic Measurements:*

During the year 1909–10 much time has been spent in the development of a strictly quantitative method for the photographic study of the spectra of fluorescent and phosphorescent bodies. This will make it possible to extend observations to bands in the violet and ultra-violet and also to study spectra that are too weak for accurate spectrophotometric determination. For this work a large quartz spectrograph and a wave-length spectrometer with photographic accessories have been imported from Hilger. For the measurement of negatives a special form of micro-comparator has been designed and constructed.

Throughout the year Dr. C. A. Pierce* has been engaged in the photographic study of phosphorescence spectra. Mr. H. E. Howe has tested the proposed method of measurement as applied to the fluorescence spectrum of

* Pierce, Physical Review, xxx, p. 663. 1910.

anthracene, and Messrs. Howe and Phelps Gage have made numerous photographic determinations of the value of various flaming arcs and other sources of light for purposes of excitation. Many tests of photographic plates have also been made.

(2) *Fluorescence Absorption:*

In the course of the year the consideration of this subject, which has for some time been in dispute, has been resumed, and by a variety of independent methods the conclusion has been reached, in conformity with the results of Camichael, Houstoun, and Wood, that the effect is either too small to detect or non-existent.*

(3) *The Conductivity of Anthracene Vapor:*

The work of Mr. H. E. Howe, begun in 1908, has been completed, and his results† have been published in the Physical Review for April 1910. Mr. Howe finds that whatever dissociation may be supposed to occur when the vapor of anthracene is excited to fluorescence does not produce a measurable effect on the conductivity of the vapor.

(4) *Studies of Phosphorescence of Short Duration:*

During 1908–09, Dr. C. W. Waggoner‡ undertook the determination of the form of the curve of decay in the case of phosphorescence of very short duration. By means of a new form of phosphoroscope especially designed for this work he was able to make observations for the complete determination of the curves of decay for substances, the phosphorescence of which had vanished or become immeasurably faint in a few hundredths of a second. He found these curves, like those depicting the decay of slowly decreasing phosphorescence, which were the only cases previously investigated, to consist of two parts, indicating two successive processes of decay merging into one another. He also found that all the general laws determined for phosphorescence of slow decay applied to the cases of phosphorescence of very brief duration.

These investigations have been continued during the past year by Mr. Carl Zeller,§ who has confirmed the results obtained by Waggoner and has in addition, by the use of the same phosphoroscope, made a detailed study of the first process in the decay of several of the phosphorescent combinations of Lenard and Klatt. Lenard, in a recent paper, has questioned the form of this portion of the curve as given by us in our earlier work, but Mr. Zeller's observations, which are carried to within less than a thousandth of a second from the close of excitation, are conclusive as to the linear relation between the reciprocal of the square root of the intensity and the time.

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* Nichols and Merritt, Physical Review, XXXI, p. 241. 1910.
† H. E. Howe, Physical Review, XXX, p. 453. 1910.
‡ C. W. Waggoner, Physical Review, XXVII, p. 109. 1908.
§ Zeller, Physical Review, XXI, p. 367. 1910.

(5) *Kathodo-luminescence:*

Preliminary work on kathodo-luminescence, an account of which was published in 1909,* is being followed up by Mr. J. A. Veazey. The greater part of the year was employed in the construction, assembling, and calibration of the apparatus, which consists of a Fluess mechanical air-pump and a rotary mercury air-pump, in tandem for the production and maintenance of high vacua; a large four-plate, motor-driven, electrostatic machine; electrostatic voltmeters for the measurement of potentials; galvanometers for determining the flow of current through the vacuum-tube and of the leakage current due to the kathodic discharge; a photometer and spectro-photometer for the optical observations. This portion of the work is now completed, and it is confidently expected that within the next few months data will be obtained which will greatly add to our definite knowledge of the laws of kathodo-luminescence.

(6) *X-ray Luminescence:*

In the course of our studies of fluorescence and phosphorescence we have from time to time used X-rays as an exciting agency and have compared the effects with those obtained by means of light. A systematic quantitative study of X-ray luminescence is now proposed and apparatus for the production of rays of the highest intensity has been ordered, on trial. This work will probably be placed in the hands of Mr. A. H. Forman, who has for two years been engaged in researches involving the use of X-rays.

(7) *The Effect of Temperature on Fluorescence and Phosphorescence:*

Quantitative studies of low temperature, down to —190° C., upon the location and intensity of the bands of fluorescence spectra, which were begun in the spring of 1909, have been continued during the past year. The measurements show that what all writers have hitherto considered as single bands and treated as units are in many cases complex in structure, consisting of an aggregation of overlapping bands, which can not be separated by spectrophotometric or photographic methods. These overlapping components are, however, frequently differently affected by change of temperature, so that the comparison of the curves giving the distribution of intensities in a fluorescence spectrum affords definite indication of the number and location of the bands of which the spectrum is composed. Numerous determinations of the effect of low temperatures upon the intensity and rate of decay of phosphorescence have also been made. Some of the results of these investigations were given in a paper read before the April (1910) meeting of the American Philosophical Society, and a further report will shortly appear in the Physical Review.

Two years ago Dr. R. C. Gibbs began the spectrophotometric study of the effect of temperature upon the absorption and fluorescence of various glasses.

* Nichols and Merritt, Physical Review, XXVIII, p. 349.

His work, which has a range from —190° C. to 400° C., has been continued during the past year and is still in progress. Many of his results have already been published in the Physical Review.*

(8) *The Distribution of Energy in Fluorescence Spectra:*

In earlier work the spectrum of the acetylene flame was used as a standard and fluorescence spectra were compared with it by determining their intensities, wave-length by wave-length, in terms of corresponding wave-lengths of the standard spectrum. To derive from such measurements the actual distribution of energy in fluorescence spectra the spectrum of the acetylene flame with that of the light from an ideal black body of known temperature has been compared once for all, thus determining the distribution of energy in the spectrum of the flame. From this a curve was plotted giving reduction factors by means of which any spectrum that has been spectro-photometrically compared with the spectrum of the acetylene flame can be described by means of a curve indicating the actual distribution of energy. The results have been published in the Physical Review.† In connection with this work, the value of a unit of absorbed energy in producing fluorescence has likewise been determined, wave-length by wave-length.

It is hoped at an early day to present for publication an extended memoir describing in full the work on fluorescence and phosphorescence thus far completed by the grantee and various collaborators under grants from the Carnegie Institution of Washington.

PHYSIOLOGY.

Loeb, Leo, University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 582. *Study of the toxic action of the poison of Heloderma suspectum.* (For previous reports see Year Books Nos. 6, 7, and 8.) $500

The investigation into the toxic action of the venom of *Heloderma* has been brought to a conclusion and a full account of the results obtained will, it is believed, be ready for publication in the course of the coming winter.

Reichert, E. T., University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 632. *Study of differentiation and specificity of homologous vital substances.* $1,500

In Publication No. 116, entitled "The differentiation and specificity of corresponding proteins and other vital substances in relation to biological classification and organic evolution: The crystallography of hemoglobins," it was shown that the hemoglobins of different species of animals differ in chemical constitution, and that these differences are specific in relation to genera, species, etc. The present research is a supplementary investigation. A number

* R. C. Gibbs, Physical Review, XXVII and XXXI.
† Nichols and Merritt, Physical Review, XXX, p. 328.

of groups of homologous vital substances, especially proteins, carbohydrates, and fats of plants, are being studied, the results in every instance being in entire support of the findings of the hemoglobin inquiry, and therefore tending to the establishment of a new and preeminently important law in biology. At least another year of inquiry must elapse before the results of this research will be ready for report in detail.

POLITICAL SCIENCE.

Rowe, L. S., University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 633. *Study of the federal system of Mexico.* (For previous reports see Year Book No. 8.) $1,500

Having completed the study of the antecedents of the constitutional system during the summer of 1909, the summer of 1910 was devoted to a study of the organization and operation of the Mexican political system. Pursuant to this purpose attention has been concentrated on the following topics:

a. The organization of the Federal Government: Relative position of the Executive and legislative authorities.
b. Division of functions between Federal and State governments.
c. Constitutional position of the States: political influence of the Federal Government over the State authorities.
d. Constitutional guarantees under the Mexican political system.

PSYCHOLOGY.

Franz, S. I., Government Hospital for the Insane, Washington, District of Columbia. Grant No. 80. *Investigation of the functions of the cerebrum.* (For previous reports see Year Books Nos. 4–8.) $1,000

In connection with grant No. 80, for investigating the functions of the cerebrum, the grantee reports progress. The work mentioned in the report of last year has been continued and some is nearing completion. During the year this work has been presented in various forms before different medical and other scientific societies, as follows:

Functions of the anterior and posterior association areas: Southern Society for Philosophy and Psychology.
The functions of the occipital lobes: Georgetown Clinical Society.
Retention of vision after extirpation of the occipital cortex in monkeys: Society of Experimental Psychologists.
Color vision and its cerebral localization: Research Workers in Experimental Biology of Washington.

During the year there have been no publications, but one article is now in press, a second has just been submitted for publication, and a third (to include a full account of the experiments on the relation of the occipital lobes to vision) will be prepared for publication during the next two months.

ZOOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. Grant No. 612. *Continuation of experimental study of heredity in small mammals.* (For previous reports see Year Books Nos. 3–8.) $1,000

The experimental studies of heredity begun in the Harvard Zoological Laboratory ten years ago have made good progress since the last report. For seven of these ten years the experiments have been fostered by the Carnegie Institution of Washington. The more important of the experiments could not have been undertaken without the aid which the Carnegie Institution grant has brought directly or indirectly.

During the past year each of the lines of investigation described in the last report have been continued and several new ones have been added.

Our present stock of animals consists of about 400 rabbits, 700 guinea-pigs, 500 mice, 1,000 rats, 400 pigeons, and 8 dogs.

The experiments have been directed toward the solution of three main problems:

(1) The nature and possible modifiability of Mendelian unit-characters.

(2) The nature of blending inheritance.

(3) The possibility of modifying inheritance by environmental influences.

Certain color-patterns of rats behave as alternative Mendelian unit-characters in heredity. They are in reality, however, quantitative variations in amount of pigmentation and are subject to individual variation, and it is believed also to modification by selection. These in brief are the conclusions which are tentatively held as a result of studying some 10,000 pedigreed rats. The purpose is, however, to double this number before venturing to draw final conclusions in a matter theoretically of much importance and in which current opinions are largely against our view.

In this laborious investigation the grantee has had the assistance of Dr. John C. Phillips, research fellow in Harvard University. With his assistance the ovarian transplantation experiments with guinea-pigs described briefly in the last report have been continued. As yet it has not been possible to duplicate the one successful case then reported. The graft takes in about 10 per cent of the transplantations made, but in only one animal, so far, have young been obtained. We propose to continue these experiments on a considerable scale to see whether characters different in nature from color-characters will behave in the same immutable fashion when residing in germ-cells which have been transplanted to a body of different character. A brief account of this work was published in September 1909 (see Bibliography, p. 48), and a fuller report is in manuscript.

Dr. Phillips and the grantee are also rearing in captivity several species of *Peromyscus,* a native field-mouse, the most widely distributed of North American mammals, and are endeavoring to hybridize species from widely

separated parts of the country, as from the Pacific Coast and New England, with a view of studying the inheritance in such crosses.

Mr. C. C. Little, a research student, has completed an important investigation of color-inheritance in mice. A preliminary paper on this work was published in September 1909 (see Bibliography, p. 48); a fuller paper is partly in manuscript. He has been able to make a more complete analysis of color-inheritance in these much-studied animals than has heretofore been made and to clear up several puzzling cases by use of the Mendelian hypothesis. Mr. Little is also beginning a systematic study of inheritance in pigeons and in dogs.

Mr. John Detlefsen, Austin Teaching Fellow in Zoology in Harvard University, is assisting in three distinct lines of work. Ovarian transplantation in frogs has given us, so far, only negative results; injection of various solutions into the reproductive glands of rats has likewise given negative results; the study of hybrids between *Cavia aperea* and the guinea-pig is giving results of interest. The curious sterility (in the male sex only) of those hybrids has been described in previous reports. At last a partially fertile male hybrid has been obtained, a one-eighth blood *aperea*, seven-eighths blood guinea-pig. A detailed study is being made of the size, color, proportions, and rate of growth of the various sorts of hybrids obtained, which range all the way from one-half blood to one thirty-second blood *aperea*. No publication has yet been made upon this investigation, though it has been in progress for some years and the results already obtained are considered important. The next year's work upon this problem should be productive. We are planning to carry it out on a considerable scale.

Mr. E. C. MacDowell, a graduate student, has aided in studying size-inheritance in rabbits. This is apparently non-Mendelian, but may prove to be a complex Mendelian case. Large numbers of animals carefully studied from birth to full maturity are needed to solve this problem. Such data are being secured, and Mr. MacDowell is proving to be a careful and critical student of them.

Selection for size in guinea-pigs (see last report) has been continued with the assistance of Mr. Detlefsen and Mr. J. W. Chapman, a graduate student in zoology. Professor Castle is studying some problems in color-inheritance in rabbits in connection with Dr. P. B. Hadley, of the Rhode Island Agricultural Experimental Station.

The Harvard authorities have greatly increased the facilities for work by building new cages, a pigeon-house, and a yard for dogs. They are now adding a new section to the basement breeding-rooms for the further extension of the experiments with rabbits and guinea-pigs. Four papers have been published since the last report. (See Bibliography, pp. 47, 48.)

Crampton, H. E., Columbia University and American Museum of Natural History, New York, N. Y. Grant No. 563. *Study of variation, mutation, heredity, and geographical distribution of Polynesian species of Partula.* (For previous reports see Year Books Nos. 6, 7, and 8.) $2,500

During eight months of 1909 a fourth journey was made to the South Pacific Islands in order to complete a survey of certain important regions of several of the Society Islands and to confirm certain observations of previous years. The field-work in this group has been entirely completed and the final laboratory investigations are rapidly reaching conclusion. On the way to New Zealand four islands of the Cook group were visited, and although this group contains few *Partula*, some interesting material was obtained for comparison with the species of the Society and other islands. Later, by way of the Tonga Islands, Samoa was visited and a final complete exploration of Tutuila was made. A survey of Upolu and Savii was made impossible by the adverse meteorological and other conditions, but certain valuable collections were made. At the Hawaiian Islands field-studies were prosecuted in order to observe the biological conditions under which the Achatinellidæ exists. In addition a study was made of the important collections of *Partula* made by Garrett, which are deposited in the Bishop Museum at Honolulu.

During the past summer the important collections of Partulæ in the Museums of Europe have been studied for the purpose of verifying the identifications of conchologists, and also for the study of type-specimens of significant species.

Gudger, E. W., North Carolina State Normal and Industrial College, Greensboro, North Carolina. Grant No. 529. *Investigation of the breeding-habits and life-history of the gaff-topsail catfish.* (For previous report see Year Book No. 7.) $300

Work under this grant has been continued, but final results have not been reached.

Mark, E. L., Harvard University, Cambridge, Massachusetts.

Grant No. 564. *Study of the maturation and early stages in the development of the ova of mice and rats.* (For previous reports see Year Books Nos. 5–8.) $100

Grant No. 492 (made jointly with W. E. Castle). *Continuation of experimental studies in heredity.* (For previous reports see Year Books Nos. 3–8, inclusive.) $500

Grant No. 564.—The paper by Dr. J. A. Long and Professor Mark on "The maturation of the egg of the mouse" is now in press. An abstract of that part of the results relating to the chromosomes was presented at the Eighth International Zoological Congress (which met at Graz, Austria, in August) under the title "Die Reifung des Eies der Maus."

The work of cross-fertilization between mice and rats by means of artificial insemination, which was unsuccessfully attempted in conjunction with Mr. S. Morgulis, has been again taken up, now in cooperation with Dr. Long. The stock of mice was shipped to Dr. Long in Berkeley, California, and a small stock of rats has been purchased for these experiments.

Grant No. 492.—A separate grant has been made to Dr. Castle for the continuation of his work in the field of this grant.

The work on parasitic hymenoptera, which was interrupted by the failure of cold-storage material, has not advanced since the last report, owing in part to inability to control the material. Consequently similar work on another group of Arthropods was begun in cooperation with a graduate student in Harvard University, Mr. R. A. Spaeth. A study of the chromosomes in maturing eggs of several species of Copepoda was undertaken with a view to ascertaining whether the chromosome conditions were sufficiently different in different species to make crossing a promising means of studying the significance of chromosomes in inheritance. A considerable amount of material has been prepared and studied far enough to show that the chromosome conditions are favorable and that interesting results may be expected, provided the desired hybrids can be produced. Although this has not yet been accomplished, we have grounds for believing that in time it can be done.

Naples Zoological Station, Naples, Italy. Grant No. 613. *Maintenance of the two tables for American biologists.* (For previous reports see Year Books Nos. 2–8, inclusive.) $1,000

During the last term the two Carnegie Institution tables have been occupied by Mr. T. Gudernatsch, April 4 to May 29, 1910, Prof. C. R. Stockard, April 15 to July 7, 1910, and Mr. M. Goldman, May 2 to June 1, 1910. Mr. Gudernatsch is a subject of the Austrian Empire. In future the principle will be strictly observed that the tables be granted only to citizens of the respective States. The Carnegie Institution of Washington has already accepted this view, and it is recognized by Austria and other governments. The observation of this principle is indeed a necessity to the Zoological Station.

The geological work of Mr. Goldman has been furthered, and it is satisfactory to state that the construction of the large physiological and chemical laboratories has extended the range of sciences previously studied in the Zoological Station. The word "table" now, indeed, in consequence of the parallel development and the growth of the whole of the Zoological Station, possesses a wider significance than merely "zoological." Morphologists, physiologists, and chemists will now find all the necessary appliances enabling them to work independently on the problem of marine biology.

During last spring 68 naturalists were simultaneously working in this station and in the last year there were altogether 164 scientists, amongst whom 14 were Americans.

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